PRELIMINARY ASSESSMENT REPORT
Ambrosia Lake – Phillips Mill
CERCLIS # NMN000606875

March 2009

New Mexico Environment Department
Ground Water Quality Bureau
Superfund Oversight Section

Table of Contents

List of Figures

List of Tables

1.0 Introduction

Under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended, 42 United States Code (U.S.C.) §§ 9601 to 9675 (CERCLA), the New Mexico Environment Department (NMED), Superfund Oversight Section (SOS) conducted a Preliminary Assessment (PA) of the Ambrosia Lake – Phillips Mill (site), McKinley County, New Mexico, CERCLIS ID#: NMN000606875 (Figure 1).

The objective of the PA is to evaluate the site using the Hazard Ranking System (Ref. 1) and the Superfund Chemical Data Matrix (SCDM) (Ref. 2) to determine if a threat to human health and the environment exists such that further action under CERCLA is warranted.

This PA of the Ambrosia Lake – Phillips Mill is also performed as part of SOS evaluation of environmental impacts of legacy uranium mining and milling activities in the San Mateo Creek drainage basin and the alluvial aquifer. This PA evaluates the threat to human health and the environmental impacts from the Ambrosia Lake - Phillips Mill has on the Ambrosia Lake valley but also the San Mateo Creek alluvial aquifer and ground water in the San Mateo Creek Basin.

2.0 Site Information

2.1 Location and description

The site is located approximately 16 miles north/northeast of Milan, New Mexico and 5 miles north of the intersection of state highway 605 and 509 (Figure 2). The geographical coordinates for the site are approximately N 35° 24' 07" and W -107° 48' 19" with an elevation of 6,956 feet above sea level (Ref. 3).

The site is approximately 1 mile east of state highway 509. Access to the site is by an unmarked dirt road off of the highway. Vehicle access is limited to the site due to a locked gate at the entrance of the dirt road controlled by Quivira Mining Company (QMC) and the United States Department of Energy (DOE) (Ref. 4). The site represents the area where the Ambrosia Lake – Phillips Mill once operated. The surface area was remediated by the DOE under Title 1 of the Uranium Mill and Tailings Radiation Control Act (UMTRCA) of 1978 (Ref. 5). The site covers approximately 290 acres of which 91 acres is an above ground disposal cell (original mill tailings pile) where identified contaminated materials are consolidated and encapsulated (Ref. 5) (Figure 3). Contaminated materials include the radioactive mill tailings, soils (on and off site) and demolition rubble (Ref. 4). The disposal cell is covered with an engineered soil cap designed to reduce migration of radon gas and water infiltration (Ref. 4). Adjacent to the disposal cell, non-contaminated demolition rubble is buried in the ground (Ref. 4).

The site is located in the elongated Ambrosia Lake valley that grades from north to south. The valley is relatively flat and surrounded by elongated mesas (Ref.

6). The landscape supports desert shrub vegetation, a mixture of shrubs (fourwing saltbush and winterfat) and grasses (Galleta, Indian ricegrass and bottlebrush squirreltail) (Ref. 7). The climate in the Ambrosia Lake valley is classified as semi-arid with an average annual precipitation of approximately 11 inches per year (Ref. 6). Approximately half of all precipitation occurres in July, August and September in the form of high intensity, convective thunderstorms (Ref. 7). The predominant precipitation in the winter months is in the form of light snow (Ref. 7). The mean annual lake evaporation in the area is 54 inches (Ref. 8). Most of the annual evaporation occurs during the months of May through October (Ref. 8).

The primary land use in the valley is grazing but at one time uranium mining and milling activities dominated (Ref. 6). The Ambrosia Lake valley at one time contained two uranium mills and 27 underground uranium mines (Ref. 9). The vast majority of mines and mills were active from the late 1950's to the early 1980's (Ref. 6).

The entire Ambrosia Lake valley, including the site is drained by the Arroyo del Puerto and its tributaries. Arroyo del Puerto is an ephemeral drainage, approximately one mile west of the site (Ref. 10). The arroyo drains this valley to the south where it then flows into San Mateo Creek (Ref. 9).

The Arroyo del Puerto drainage basin is a sub-basin of the larger San Mateo Creek drainage basin. The San Mateo Creek drainage basin (HUC 1302020703) comprises approximately 321 square miles within the Rio San Jose drainage basin (Ref. 9). The San Mateo Creek drainage basin includes 85 legacy uranium mines and 4 legacy mill sites that may have contributed to degradation of ground water quality within this basin (Ref 9). This PA of the Ambrosia Lake – Phillips Mill is performed as part of the New Mexico Superfund Oversight Sections examination of legacy uranium mining and milling activities in the San Mateo Creek Basin.

2.2 Operational History and Ownership

Phillips Petroleum Company operated the uranium mill from 1958 through 1963 (Ref. 5). The mill used an alkaline pressure leach process to extract uranium from ore (Ref. 4). During those five years of operation, 3 million tons of radioactive tailings were created and stored on site. The mill was purchased by United Nuclear Corporation (UNC) in 1963 (Ref. 5). All milling ceased in 1963 (Ref. 5). In the 1970's, UNC used portions of the mill site as a ion exchange facility to extract uranium from mine water until 1982 (Ref. 5).

Title 1 of the UMTRCA of 1978 authorized the DOE to remediate identified uranium mill sites to prevent or minimize environmental hazards for the protection of the public health, safety and welfare (Ref. 11). As required by UMTRCA of 1978, the Environmental Protection Agency (EPA) promulgated environmental standards that required DOE to provide long term stabilization of residual radioactive material, control radon releases to air and protect water (Ref. 12). DOE remediated the site between 1987 and 1995 (Ref. 5). Remediation at the site consisted of consolidating and encapsulating all residual radioactive contaminated material on site in an engineered disposal cell. The disposal cell occupies 91 acres of the 290-acre site (Ref. 5). The State of New Mexico held title to land during cleanup activities as required. DOE currently is the owner of the site and is responsible for long term care (Ref. 4).

2.3 Regulatory History

DOE remediated surface impacts at the site under Title 1 of UMTRCA 1978 (Ref. 5). Remedial work was conducted at the site from 1987 through 1995 (Ref. 4). Long term surveillance of the disposal site is responsibility of DOE (Ref. 4). Yearly inspections of the site are conducted by DOE (Ref. 4). Surface inspections include any notable changes to the surface area of the site including significant erosion, damage to fences and signage to the site. The disposal cell is inspected for changes to the cap that can include vegetative growth, erosion, settlement and seepage at the base. No ground water remediation or monitoring is required at the site due to the determination by DOE that the upper aquifer (alluvial/weathered Mancos Shale/Tres Hermanos-C) under the disposal site is of limited use (Ref. 8). Limited use ground water is defined as ground water that is not a current or potential source of drinking water because the quantity of water reasonably available for sustained continuous use is less than 150 gallons per day (Ref. 12). Due to the above determination by DOE and concurrence from the Nuclear Regulatory Commission (NRC), DOE was not required nor did they propose or implement a long term monitoring strategy or ground water compliance plan for the site (Ref. 13). The New Mexico Water Quality Control Commission (NMWQCC) protects all ground water of 10,000 milligrams per liter total dissolved solids (TDS) concentration or less. Due to objections from NMED, two monitor wells are still sampled every three years as a best management practice for the purposes of monitoring the disposal cell performance (Ref. 13). Ground water quality in the uppermost aquifer downgradient the disposal cell continues to exceed federal maximum contaminate levels (MCLs) and state ground water standards for several water quality parameters (uranium, molybdenum, selenium, sulfate and nitrate) from seepage from the disposal cell (Table 1).

2.4 Previous Environmental Investigation

DOE under Title 1 of UMTRCA 1978 was required to cleanup inactive uranium mill sites such as this site (Ref. 11). DOE remediated these sites in accordance with environmental standards promulgated by the EPA in Title 40 CFR Part 192 (Ref 12).

As part of the cleanup, DOE performed several studies and prepared documents. The documents include; Environmental Assessment (EA) (1985) (Ref. 6), Remedial Action Plan and Site Stabilization Design Volume I and II (1991) (Ref. 8 and Ref. 20), the Long Term Surveillance document (1998) (Ref. 4) and the Ground Water Compliance Action Plan (1998) (Ref. 13). Annual inspection reports have been developed since 1999 and ground water sampling reports are developed every three years starting in 2001.

In 1968. the earliest study of the Ambrosia Lake valley was published by the New Mexico Office of the State Engineer. The report is titled "Geology and Ground Water Occurrence in Southeastern McKinley County, New Mexico." It provides the earliest view of ground water resources and their use in the Ambrosia Lake valley. The study provides some ground water quality data prior to beginning of uranium mining in the Ambrosia Lake valley which indicate the Westwater Canyon to be the principle aquifer in the Ambrosia Lake valley with fair to good ground water quality for domestic use (Ref. 14).

In 1975, at the request of NMED, EPA Region 6 implemented a study of the uranium mining and milling activities of the Grants Uranium Belt which includes the Ambrosia Lake valley to determine the impact of these activities on surface and ground water in the area. The study details contamination from uranium mining and milling activities of the surface water and ground water resources in the Grants Mineral Belt, New Mexico (Ref. 15).

In 1977, Los Alamos Scientific Laboratory published a study titled "Geology and Hydrology in the Vicinity of the Inactive Uranium Mill Tailings Pile, Ambrosia Lake, New Mexico." The study examined the geology and hydrology of the immediate area around the inactive Phillips mill tailings pile. Included in the study was the investigation of the major transport mechanisms of the tailings and possible contaminants from the pile that included wind erosion, surface water runoff, movement of ground water beneath the pile and gaseous diffusion from the pile. The study concluded that some seepage from the tailing pile into alluvium ground is on-going and that the transport of tailings by wind and storm water is a concern to the surrounding environment (Ref. 16).

In 1979, Robert Brod's thesis titled "Hydrogeology and water resources of the Ambrosia Lake – San Mateo Area McKinley and Valencia Counties, New Mexico was submitted to New Mexico Institute of Mining and Technology. The thesis examined the ground water resources and the effects of uranium mining and milling on the ground water system in the Ambrosia Lake valley (Ref. 17).

In 1980, New Mexico Environmental Improvement Division (predecessor of NMED) published a report titled "Water Quality Data for Discharges from New Mexico Uranium Mines and Mills" which provided data obtained from samples collected in 1977, 1978 and 1979. Mines and mills were not required to treat water until the mid 1970s. The study examined mine water treatment practices and there effectiveness. Water treatments reduced radionuclides but were ineffective in reducing metal such as uranium, selenium and molybdenum. Discharges from mines and mills were sampled in the Ambrosia Lake valley (Ref. 18).

In 1986, NMED produced a study titled "Impacts of Uranium Mining on Surface and Shallow Ground Waters Grants Mineral Belt, New Mexico." This study examined the impacts that mine dewatering and milling discharges had on surface water and alluvium ground water in the Arroyo del Puerto and San Mateo Creek. The study concluded that these discharges in the Ambrosia Lake valley had contaminated alluvium ground water for use in irrigation, livestock watering and domestic supply because of elevated concentrations of molybdenum, selenium and gross alpha activity (Ref 19).

3.0 Site Investigation

3.1 Source/Waste Characteristics

The primary waste source identified at the site is the disposal cell (Figure 3). The disposal cell contains all identified radioactive contaminates from the remediation of the site including tailings, windblown and waterborne surface soil and building rubble. The main tailings pile was stabilized in place with other contaminated materials incorporated into the pile. In total, the disposal cell contains 5.2 million cubic yards (yds^3) of radioactive materials of which includes 2.7 million yds^3 of tailings, 1.1 million yds^3 of contaminated material including soil, and 1.4 million yds^3 of building rubble (Ref. 4). The contaminated material and soil includes, 277,000 yds^3 from the mill yard, ore storage area and the adjacent Ann Lee mine area; 151,000 yds^3 from the protore storage and leach pad areas; and 664,000 yds^3 of contaminated soil from the surrounding area (Ref 20). It should be noted that UNC used 0.36 million tons of tailings from the site to backfill the main shaft at the adjacent Ann Lee mine (Ref 4).

The disposal cell covers an area of approximately 91 acres that measures 2,500 feet by 1,600 feet. The pile rises above the surrounding terrain by approximately 50 feet. The cover consists of a 30-inch radon/infiltration barrier comprised of weathered mancos shale material from a borrow source one mile north of the site. Over the radon barrier is a six inch thick granular bedding material (capillary zone). The outer material is a rock rip rap material for erosion protection with six inches on top of the pile and 12 inches on the side slopes (Ref. 4).

The radon barrier is to reduce radon migration from the pile to less than 20 pico-curies per meter^2 per second (pCi/M^2/S). The radon barrier is also considered an infiltration barrier which is designed to minimize the rate of water infiltration into the tailings (Ref. 4).

3.1.1 Source/Waste Description

During the milling process from 1958 to 1963, 3 million yds^3 of tailings were created from the uranium ore (Ref. 20). It was estimated that for every 1 yd^3 of tailings from the milling process up to five tons of waste water were produced. In the five years of milling up to 11,038 acre feet of waste water (3.6 billion gallons) was discharged onto the tailings pile (Ref. 4). UNC later operated an Ion Exchange (IX) plant at the site that removed uranium from mine water. Mine water from three nearby mines was collected in a pond near the IX plant. This water was recirculated back into the mines after running through the IX plant (Ref. 18). The saturation of the alluvium in the area of the site is related to the mine water discharged from the adjacent Ann Lee mine, the infiltration of water from the unlined mill process (makeup) ponds and pore fluids infiltrating from the tailings pile (Ref. 4).

DOE determined that the hazardous constituents within the tailings pore fluids were mostly metal and metalloid elements associated with the uranium milling process. Concentrations of arsenic, barium, cadmium, lead, molybdenum, nitrate, selenium, silver, uranium and activities of gross alpha, radium-226 and -228 exceeded the maximum concentration limits (MCLs) established by the EPA in tailings pore fluid samples collected from lysimeters or well points (Ref. 8). Antimony, cobalt, copper, cyanide, fluoride, nickel, tin, vanadium and zinc are inorganic hazardous constituents were present in tailings pore fluid at concentrations higher than the laboratory method detection limit. No organic hazardous constituents were above laboratory method detection limits (Ref. 8).

Ground water monitoring wells sampled during DOE's site investigation of the Ambrosia Lake tailings pile identified chromium, molybdenum, nitrate, lead, selenium, silver, uranium and radium-226 and -228 and gross alpha in the saturated alluvium beneath the tailings pile that exceeded the EPA MCL's (Ref. 8).

3.2 Ground Water Pathway

3.2.1 Hydrogeology

The following hydrostratagraphic units are found under the site in descending order: alluvium (Quarternary), weathered Mancos Shale (Cretaceous), Tres Hermanos Sandstones of the lower Mancos Shale (Crestaceous), the Dakota Sandstone (Crestaceous), and the Westwater Canyon Member of the Morrison Formation (Jurassic) (Ref. 8) (Figure 4).

The alluvium aquifer was reported to contain minor amounts of water prior to mining in the Ambrosia Lake valley (Ref. 14). There were no known wells in the alluvial aquifer before uranium mining began in the Ambrosia Lake valley in the late 1950's (Ref. 14). In the Ambrosia Lake valley it was estimated that between

10 and 17 million gallons per day of ground water was pumped to dewater mines from the late 1950's through 1980 in the Ambrosia Lake valley (Ref. 18). Much of this mine water was discharged to the Arroyo del Puerto or its tributaries making it a perennial stream (Ref. 20). This perennial flow continued several miles past the confluence with San Mateo Creek (Ref. 15). Considerable infiltration and recharge from this water into the alluvium would occur along the arroyo bed due to the coarser materials (Ref. 19). At the site, the alluvial aquifer was reported to be saturated in the area of the disposal cell artificially due to past discharges from milling activities, seepage from the tailings pile and mine dewatering in the area (Ref. 8).

The alluvium under the disposal cell at the site is identified as several feet thick along the eastern edge and dipping to 60 feet thick along the western edge (Ref. 8). Groundwater flow in the alluvium under the disposal site is to the southwest toward the Arroyo del Puerto (Ref. 8). At the time of DOE's site investigation in the late 80's, monitoring wells placed in the alluvium showed the aquifer to be saturated in the local vicinity of the tailings pile (Ref. 8). The extent of the saturation in the alluvium southwest of the site toward the Arroyo del Puerto was not fully investigated. Contractors investigating the Rio Algom Uranium mill, one mile to the west of the site along the Arroyo del Puerto identified a paleochannel in the deeper alluvium along the western edge of the Phillips Mill disposal cell (Ref. 21) (Figure 5). This incised paleochannel trending southwest would make it a tributary to the main paleochannel of the Arroyo del Puerto (Ref. 21). These alluvium filled incised channels create an under drain for the valley (Ref. 21). Alluvial thickness of 100 feet was reported near the Arroyo del Puerto (Ref. 21). The paleochannel would provide a groundwater pathway in the alluvium from the site to the alluvium under Arroyo del Puerto (Ref. 21).

The alluvium deposited along the surface of the eroded weathered Mancos Shale, dips in the direction of the surface topography, to the south and southwest (Ref. 8). Conversely, the bedrock units below the alluvium follow the regional dip to the northeast (Ref. 8) (Figure 3). The Tres Hermanos Sandstones below the disposal site consists of three units, in descending order they are the Tres Hermanos C, B and A (Ref 8). The Tres Hermanos C Sandstone is spilt into two units the Tres Hermanos C1 and C2 units (Ref. 8). All Tres Hermanos Sandstone units are separated by strata of Mancos Shale (Ref. 8). Mancos Shale subcrops in the alluvium under the eastern edge of the disposal cell and the Tres Hermanos-C subcrops under the alluvium along the western edge of the disposal cell (Ref. 8). The Tres-Hermanos-B subcrops in the alluvium under the Arroyo del Puerto west of the site (Ref. 8) (Figure 3). Groundwater flow in the bedrock below the disposal site flows to the northeast following the regional dip. Because the topography slopes to the southwest, progressively older bedrock formations subcrop beneath the alluvium in this direction (Ref. 8). Further to the south the alluvium under the Arroyo del Puerto is up to 100 feet thick and is in contact with subcrops of the Dakota sandstone and the Morrison Formation (Ref.

17). Ground water in the alluvial aquifer can recharge these bedrock units as they subcrop along the alluvium (Ref. 17) (Figure 3).

The Westwater Canyon member is described as the principle aquifer in the Ambrosia Lake valley (Ref. 14). The Westwater Canyon aquifer was described as producing adequate water for domestic, livestock and industrial uses and is described as good to fair in quality (Ref. 14). The Westwater Canyon member is also the main formation in which the uranium ore was mined from in the Ambrosia Lake valley (Ref. 14). The uranium mines in this area had to dewater creating a cone of depression in the Ambrosia Lake valley down through the Westwater Canyon member (Ref. 22).

3.2.2 Ground Water Quality

There is some data available to identify pre-mining ground water quality in the Ambrosia Lake valley (Ref.14). The data available suggests that the West Water aquifer was of fair to good quality (Ref. 14). There were no known wells in the alluvial aquifer before uranium mining began in the Ambrosia Lake valley in the late 1950's (Ref. 8 and Ref. 14).

Studies by NMED and EPA concluded mine dewatering effluents and milling seepage adversely affected surface water chemistry and caused contamination of the shallow alluvial aquifer from the Ambrosia Lake area downgradient into San Mateo Creek (Ref. 19 and Ref. 15). Uranium mining and milling impacts on the degradation of alluvial ground water was pronounced in the Ambrosia Lake valley. This was due to the large amounts of mine water discharged to the Arroyo del Puerto, the poor quality of discharged water and the hydrogeologic conditions along Ambrosia Lake drainages resulting in relatively rapid infiltration rates (Ref. 19). Raw uranium mine waters in the Ambrosia Lake valley contain elevated concentrations of radionuclides, uranium, selenium, molybdenum and sulfate (Ref 19). Other elevated concentrations occasionally detected are barium, arsenic and vanadium. Treatment of raw mine waters did not begin until the mid 1970's but this treatment only reduced radionuclides. The other contaminants were not affectively treated (Ref. 19).

The hydrostatic units identified by DOE to be impacted by seepage from the site are the alluvium/weathered Mancos Shale and Tres Hermanos-C (Ref. 20). Sampling data from the site shows that ground water downgradient of the disposal cell continues to exceed both EPA MCLs and New Mexico ground water standards (Table 1). DOE also identified a pathway for contaminated ground water under the site to migrate through the Tres Hermanos sandstones, down mine shafts and vent holes into the Westwater Canyon aquifer that has contributed to the contamination of this aquifer (Ref. 4). Ground water in the Westwater Canyon member has been found to exceed the EPA MCLs for cadmium, chromium, lead, molybdenum, selenium, silver, uranium and activities of radium 226, radium 228 and gross alpha (Ref 20).

Mine dewatering activities have ceased in the Ambrosia Lake valley. Ground water levels are recovering as ground water migrates back into the dewatered areas. Estimates of the time required to depressurize the regional cone of depression range from several hundred to several thousand years (Ref. 22). Recent ground water samples taken from the West Water Canyon aquifer from mine vents at the nearby Section 27 mine continues to exceed EPA MCLs for uranium and radium-226 (Ref. 22).

3.2.3 Ground Water Targets

No domestic wells were identified within a 4-mile radius of the site based on the New Mexico Office of the State Engineer database (Ref. 23) (Figure 6). The 2000 US Census identified a total of 8 people living in a 4-mile radius of the site (Ref. 24). Two ranch headquarters (Harris and Berryhill) are the only two known residences identified in the four mile radius of the site (Ref. 8). The Berryhill Ranch well was in the Westwater Canyon aquifer but went dry due to mine dewatering activities in the 1970s (Ref. 8). Domestic water to this ranch was and still is supplied by pipeline from a supply well at the nearby Quivira Mine No. 17 (Ref. 8). The Harris ranch headquarters receives water from a stock well in the San Andres limestone at a depth greater than 3,000 feet (Ref. 8). No sampling data has been identified for either well. For purposes of this PA, there a total of eight people deriving domestic water from two wells in a 4-mile radius of this site.

During the mining and milling activity it was estimated that over two hundred people lived in the Ambrosia Lake valley (Ref. 14). Certainly the population is greatly diminished with the mines and mills closed. Most of the wells in the Ambrosia Lake valley have been plugged or are no longer in use (Ref. 8). A series of dwellings and seven domestic wells exist to the south at the intersection of state highway 509 and 605 but all are outside the four mile radius of the mill (Figure 6).

The Westwater Canyon member is described as the principle aquifer in the Ambrosia Lake valley producing adequate water for domestic, livestock and industrial uses (Ref. 14). Legacy mining and milling activities in the Ambrosia Lake valley has substantially degraded water quality and reduced the quantity of ground water resources (Ref. 8). Further investigation is required to determine potential impacts from the mill site to the Westwater Canyon member and ground water in the San Mateo Creek Basin.

3.3 Surface Water Pathway

3.3.1 Hydrology

The watershed above the site and disposal cell covers an area of 3.14 square miles (Ref. 8). Two ephemeral channels will carry runoff toward the disposal cell from an area northwest of the site on Roman Hill on San Mateo Mesa (Ref. 8). These channels above the site will flow only in response to local precipitation events.

All drainage channels in the Ambrosia Lake valley were ephemeral including the Arroyo del Puerto prior to the mining and milling activities. It was estimated that between 10 and 17 million gallons per day of ground water was pumped to dewater mines from the late 1950's through 1980 in the Ambrosia Lake valley (Ref. 18). Much of this water was directly discharged to Arroyo del Puerto and its tributaries (Ref. 14). It was not until the mid 1970's that mines started impounding and treating this mine water before discharging to the Arroyo del Puerto and its tributaries (Ref. 19). Measurements from 1979 through 1982 estimated flows of 3.3 million gallons per day in Arroyo del Puerto due mine dewatering discharges (Ref. 19). Discharges to the Arroyo del Puerto were probably much greater prior to the mines treating this water. These discharges made the Arroyo del Puerto a perennial stream carrying water past the confluence with San Mateo Creek several miles where the remaining flow would infiltrate the surface (Ref. 15). With mine dewatering discontinued, the Arroyo del Puerto and its tributaries have returned to its pre-mining condition as an ephemeral drainage. They flow only in response to local precipitation events.

DOEs site investigation determined that some waste water from the mill and mine dewatering was probably discharged to Voght tank, a surface water catchment to the southeast of the site and tributary to Arroyo del Puerto (Ref. 4). A 6,000 foot canal connected the site to the Voght Tank (Ref. 8). Similar canals from mines located near the mill led to Voght Tank (Ref. 8). Any volumes of waste water from the mill discharged to Voght Tank remains unknown (Ref. 8).

3.3.2 Surface Water Quality

Surface water samples collected in the 1970's and 1980's showed that the water quality in Arroyo del Puerto exceeded water quality standards for livestock watering (Ref. 19). It is unknown whether surface water was ever used for domestic drinking water.

There is no known recent sampling data from surface water catchments in Arroyo del Puerto and its tributaries, such as Voght tank (Figure 1). It is unknown that surface water contained there meets standards for livestock watering and wildlife habitat.

DOE in its remedial activities of the site, investigated the canal from the stand point of radioactive soil but did not investigate the water quality of Voght Tank.

3.3.3 Surface Water Targets

Potential targets would include livestock and wildlife that utilize surface water in these catchments. Other potential targets could be recreational users of water in these catchments. Access to Voght Tank is limited but other catchments downgradient along Arroyo del Puerto may be accessed (Figure 2).

3.4 Soil Exposure Pathway

DOE identified radioactive soil due to windborne and water runoff from the tailings impoundment and mill site. DOE surface remedial activities identified approximately 644,000 cubic yards of contaminated soils to be excavated and encapsulated into the disposal cell. Soils were removed from the site property and extending over 230 acres into surrounding properties. Soils were screened both vertically and horizontally. The criterion used for removal and encapsulation was soils exceeding 5 pCi/g Radium-266 (Ref. 8).

3.5 Air Pathway

This pathway was not examined during this PA. Eight residents are identified within a four mile radius of the Site and a historic distribution of wind borne contaminates has been documented. The nearest residence is within a three mile radius of the site

4.0 Summary and Conclusion

Seepage from the tailings and disposal cell has and continues to release contaminates to the alluvium aquifer. There is evidence that this site had the potential to contribute to the contamination of the alluvium aquifer along the Arroyo del Puerto and on into San Mateo Creek. Prior investigations have found that this site has released and contributed to the contamination of the Westwater Canyon aquifer. Monitoring data continues to show that the alluvium and the Tres Hermanos B ground water downgradient of the disposal cell of this site continues to exceed EPA MCLs and New Mexico state ground water standards for uranium, molybdenum, selenium, nitrate and sulfate (Table 1).

The previous period of uranium mining and milling activity stimulated the temporary development of the Ambrosia Lake valley and substantially degraded water quality and reduced the quantity of ground water resources (Ref. 8).

Ambrosia Lake – Phillips Mill is listed as a Title 1 inactive uranium mill in UMTRCA of 1978 under Section 102(a) (Ref.11). CERCLA, Section 101, Paragraph 22 (C) has identified those sites listed in UMTRCA of 1978 in Section 102(a) as exempt from further removal actions under CERCLA, Section 104 (Ref. CERCLA). Based on this, further investigation of this site is warranted to determine the extent of ground water contamination from the site. Further investigation of the Ambrosia Lake - Phillips Mill should evaluate:

- The West Water Canyon aquifer.
- The alluvial ground water along the Arroyo del Puerto.
- Metal concentrations of surface soils in the area surrounding the Phillips Mill.
- Sediments down-gradient of the Phillips Mill for metals and radionuclides.
- Surface water quality of catchments down-gradient of the Phillips Mill such as Voght Tank for metals and radionuclides.

5.0 References

1. U.S. EPA, 1990, 40 CFR Part 300, Hazardous Ranking System Final Rule, December 14, 1990. p. 51532- 51667.

2. U.S. EPA, 1996, Superfund Chemical Data Matrix – User Version, Windows Version 1.0 Developed by the Office of Emergency response and Remedial Response, U.S. EPA September 1997.

3. Google, "Aerial Photo of the Ambrosia Lake Disposal Cell and Surrounding Area." Downloaded from Google Earth on June 10, 2008.

4. U.S. Department of Energy, July 1996. "Long-term surveillance plan for the Ambrosia Lake, New Mexico disposal site." Environmental Restoration Division UMTRA Project Team. DOE/AL/62350-211 Rev. 1.

5. U.S. Department of Energy, August 2006. "Ambrosia Lake, New Mexico disposal site fact sheet."

6. U.S. Department of Energy, June 1987, "Remedial Action at the Ambrosia Mill Tailings Site Ambrosia Lake, New Mexico." Environmental Assessment. DOE/EA – 0322.

7. U.S. Department of Agriculture, "Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin" Natural Resource Conservation Service. U.S.D.A. Handbook 296.

8. U.S. Department of Energy, November 1991. "Remedial action plan and site conceptual design for the stabilization of the inactive uranium mill tailings site at Ambrosia Lake, New Mexico." Uranium Mill Tailings Remedial Action Project. Vol 2: Appendices D and E. UMTRA-DOE/AL 050516.0000.

9. New Mexico Environment Department. January 2008. "San Mateo Creek Basin Legacy Uranium Sites Cibola and McKinley Counties, New Mexico." Map prepared by Suzan Arfman for the Superfund Oversight Section.

10. U.S. Geological Survey, 1963, 7.5 minute topographic map Ambrosia Lake, San Lucas Dam, San Mateo and Dos Lomas, N. Mex (Photorevised 1980).

11. U.S. Nuclear Regulatory Commission. June 2002, "Uranium Mill Tailings Radiation Control Act of 1978." Nuclear Regulatory Legislation. Office of General Counsel. NUREG-0980 Vol. 1, No. 6.

12. Code of Federal Regulations, July 2004, Title 40, Part 192. "Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites." Office of the Federal Register National Archieves and Records Adminstration.

13. U.S. Department of Energy. July 1998. "Ambrosia Lake Ground Water Compliance Action Plan."

14. Cooper, James B., and Edward C. John, 1968. "Geology and ground-water occurrence in southeastern McKinley County, New Mexico." New Mexico State Engineer Technical Report 35.

15. U.S. Environmental Protection Agency, September 1975. "Water quality impacts of uranium mining and milling activities in the Grants Mineral Belt, New Mexico." EPA 906/9-75-002.

16. Purtymun, W.D., Caroline L. Wienke, and David R. Dreesen, June 1977. "Geology and hydrology in the vicinity of the inactive uranium mill tailings pile, Ambrosia Lake, New Mexico. Los Alamos Scientific Laboratory. LA-6839-MS Informal Report.

17. Brod, Robert C., June 1979. "Hydrogeology and water resources of the Ambrosia Lake—San Mateo area, McKinley and Valencia counties, New Mexico." New Mexico Institute of Mining Technology Master of Science thesis.

18. Goad, Maxine S., Charles L. Nylander, Bruce M. Gallaher, John G. Dudley, and Betty L. Perkins, July 1980. "Water quality data for discharges from new Mexico uranium mines and mills." New Mexico Health and Environment Department Water Pollution Control Bureau.

19. Gallaher, Bruce M. and Steven J. Cary, September 1986. "Impacts of uranium mining on surface and shallow ground waters, Grants Mineral Belt, New Mexico." New Mexico Environmental Improvement Division.

20. U.S. Department of Energy, November 1991. "Remedial action plan and site conceptual design for the stabilization of the inactive uranium mill tailings site at Ambrosia Lake, New Mexico." Uranium Mill Tailings Remedial Action Project. Vol 1: Appendices A, B and C. UMTRA-DOE/AL 050516.0000.

21. Rio Algom Mining LLC. July 2007. "Geomorphic Evaluation of Arroyo del Puerto Drainage Ambrosia Lake Area." Prepared by AMEC. SUA-1473.

22. United Nuclear Corporation, November 2007. "Section 27 Mine Stage I Abatement Investigation Report Ambrosia Lake Valley, New Mexico." Prepared by Intera Incorporated.

23. New Mexico Office of the State Engineer, 2003. Data downloaded from the Water Administration Technical Engineering Resource System (WATERS Database) at http://www.seo.state.nm.us/water-info/index.htm

24. U.S. Census Bureau, accessed and downloaded April 23, 2007. http://factfinder.census.gov/servlet/DownloadCenterServlet

25. U.S. Environmental Protection Agency. December 2002 "Comprehensive Environmental Response, Compensation, Liability Act of 1980." Q:\COMP\ENVIR2\CERCLA

26. U.S. Department of Energy, March 2008, "November 2007 Ground Water Sampling at the Ambrosia Lake, New Mexico, Disposal Site." Office of Legacy Management. DOE-LM/1599-2005.

27. U.S. Department of Energy, March 2005, "September 2004 Ground Water Sampling at the Ambrosia Lake, New Mexico, Disposal Site." Office of Legacy Management. DOE-LM/GJ810-2005.

28. U.S. Department of Energy, December 2002. "2002 Annual Site Inspection And Monitoring Report for Uranium Mill Tailings Radiation Control Act Title 1 Disposal Sites." Idaho Operations Office. Grand Junction, Colorado. GJO-2002-392-TAC.

29. New Mexico Environment Department. July 2006. "New Mexico Water Quality Control Commission Regulations." 20.6.2 NMAC. New Mexico Water Quality Control Commission.

30. U.S. Environmental Protection Agency. "List of Contaminants and Their Maximum Contaminant Level." Downloaded June 10, 2008. http://www.epa.gov/safewater/contaminants/index.html

31. U.S. Department of Interior. 1978. "Surface Management Status, Grants New Mexico." Bureau of Land Management. Grants Quadrangle 1:100,000-Scale Series (Topographic).

FIGURES

Figure 1. Ambrosia Lake - Phillps Mill

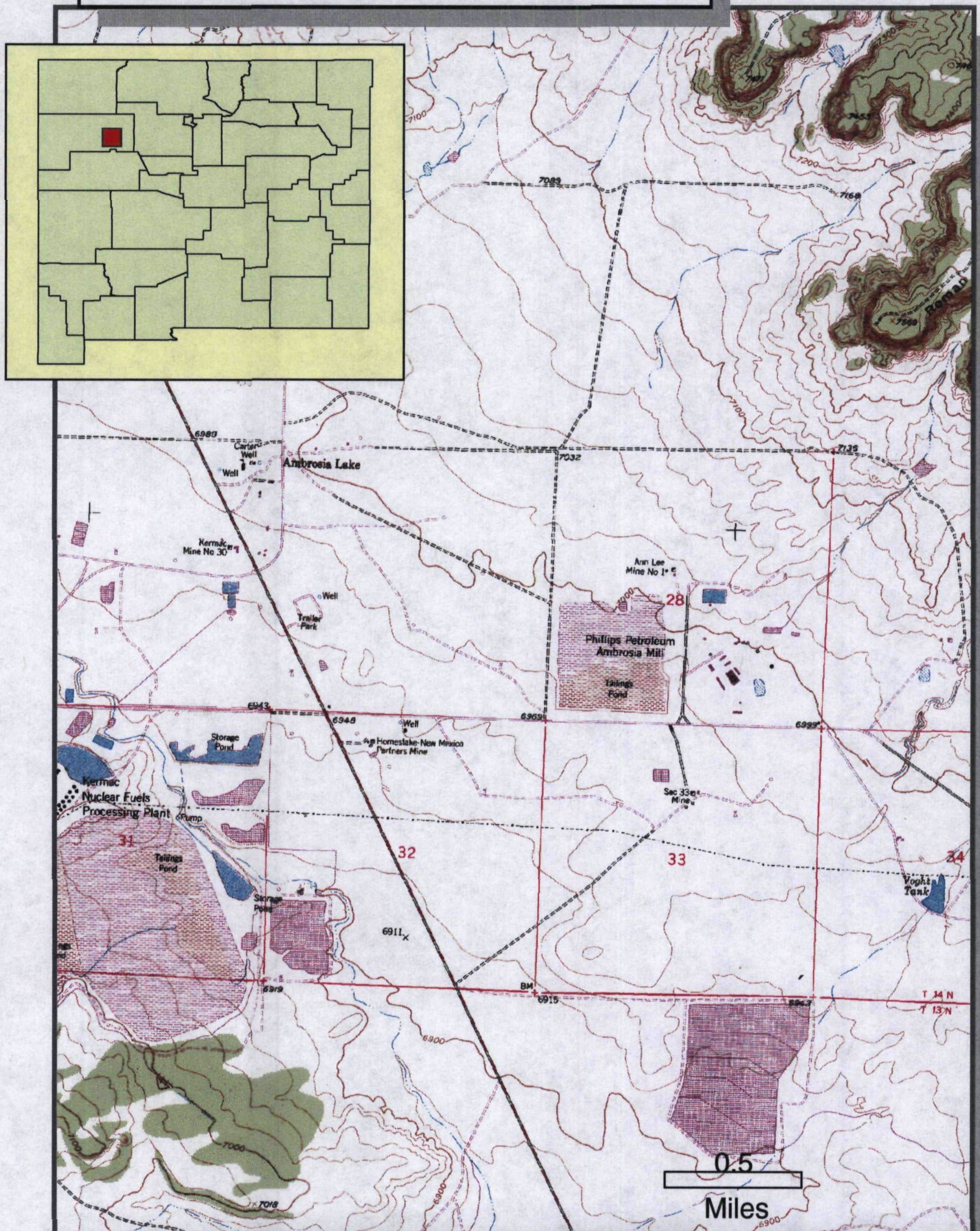
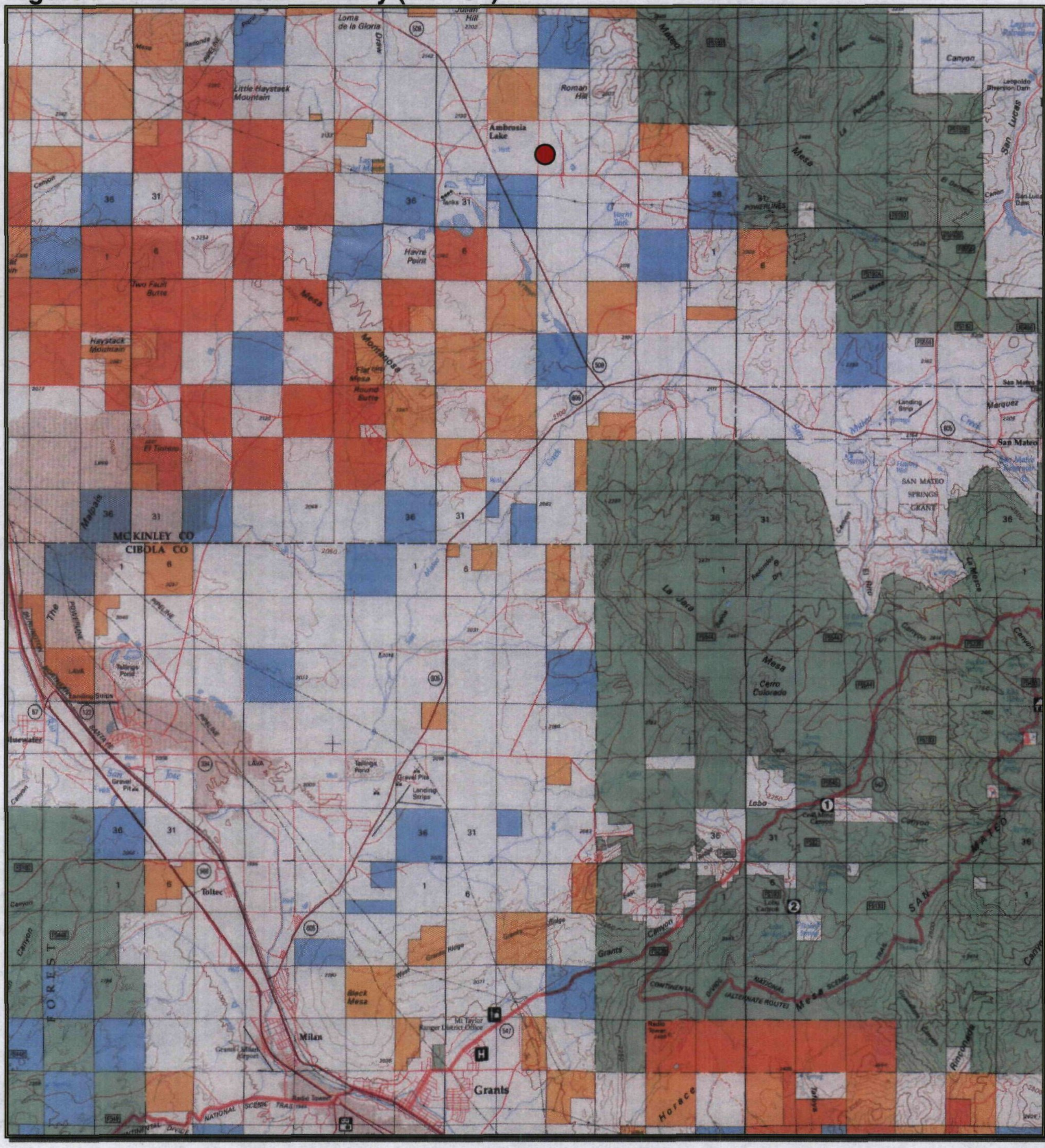


Figure 2. Ambrosia Lake Valley (Ref. 31)



● - Ambrosia Lake – Phillips Mill Site

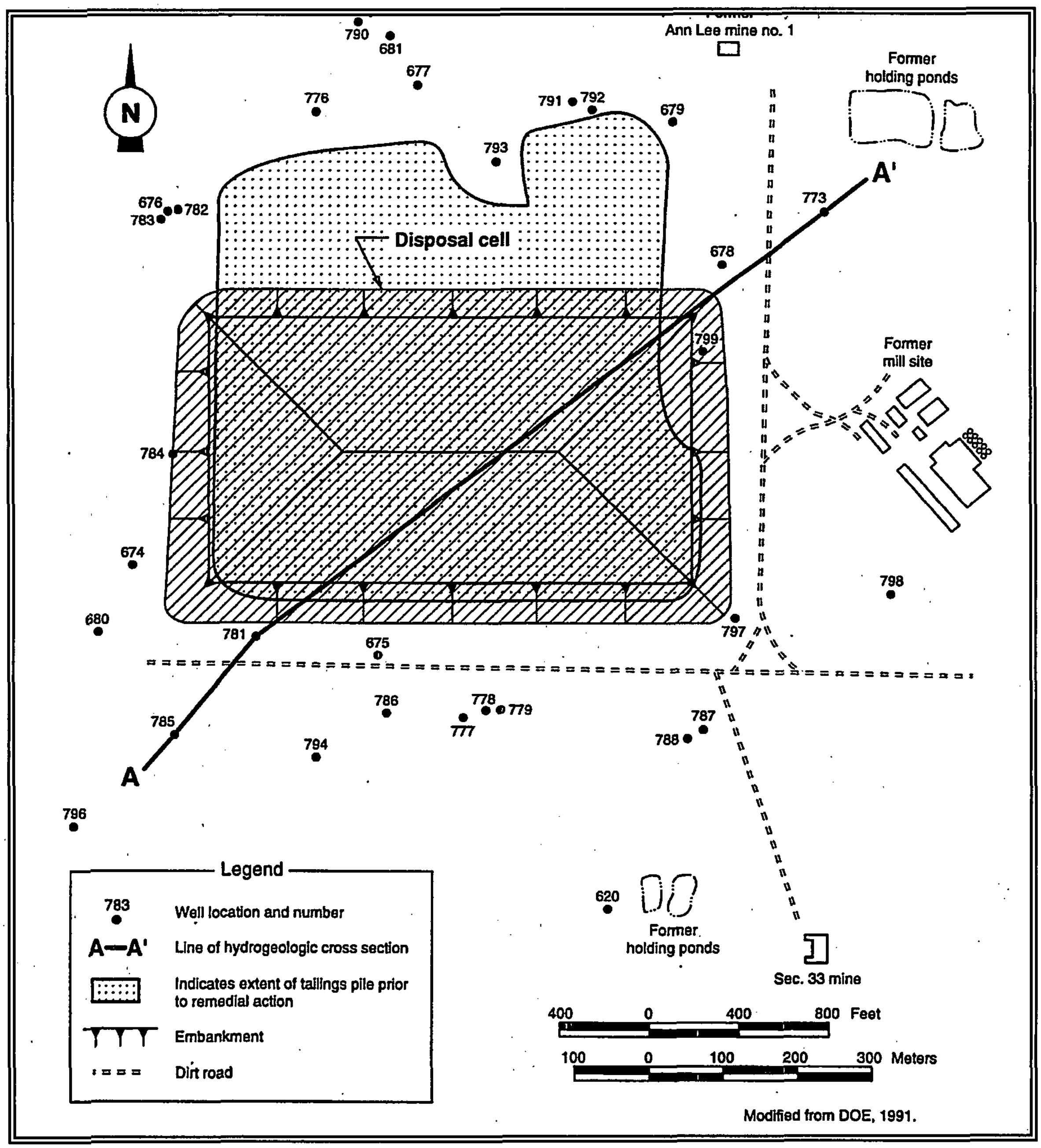


Figure 3. Former Mill and Tailings Site and Current Disposal Cell (Ref. 4).

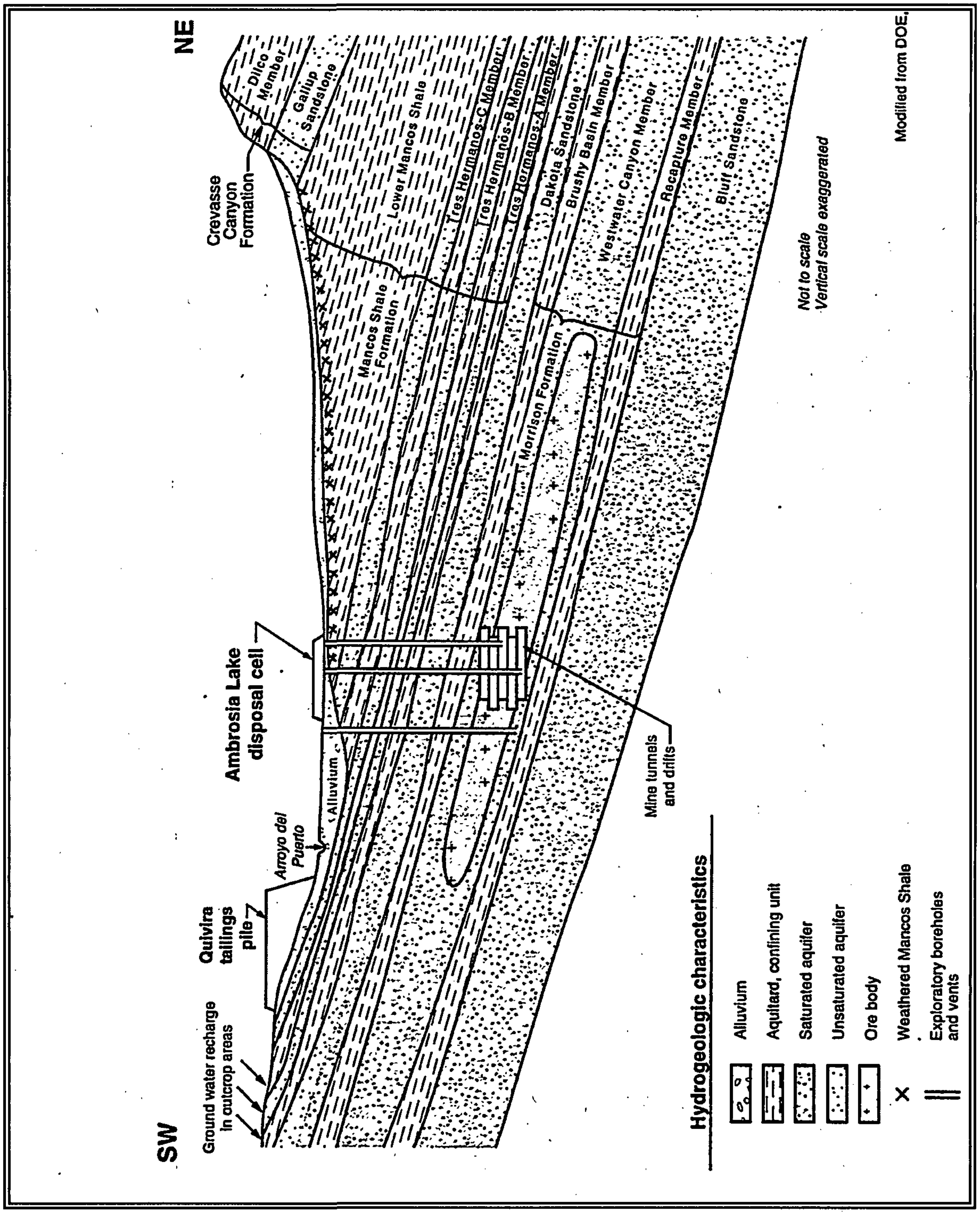


Figure 4. Hydrostratigraphy for Ambrosia Lake – Phillips Mill (Ref. 4).

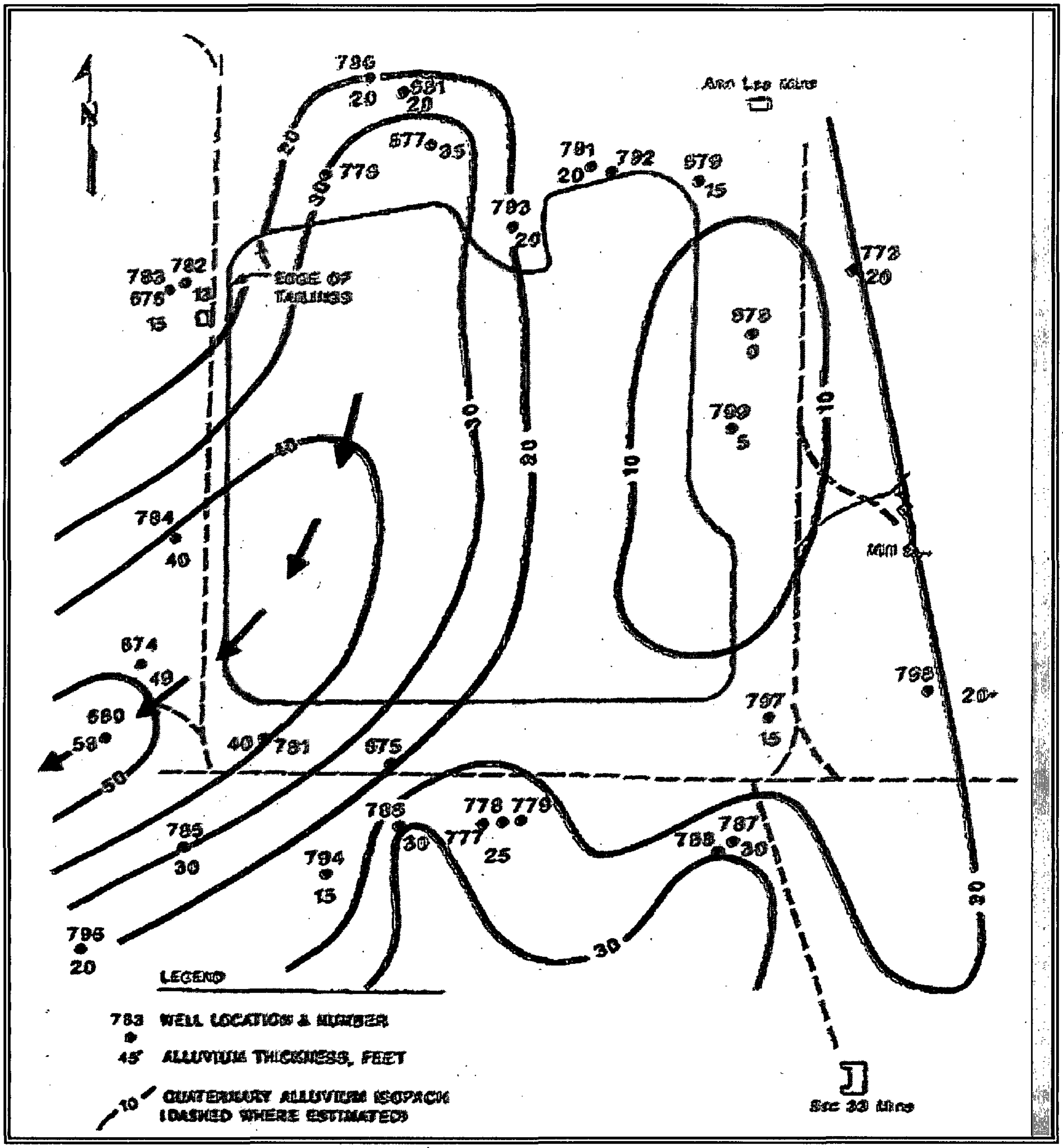


Figure 5. Paleochannel under the Disposal Cell, Ambrosia Lake – Phillips Mill (Ref. 21).

Figure 6. Private Wells, 4-Mile Radius Map (Ref. 10 and Ref. 23)

TABLES

Table 1. Summary of Post Remediation Ground Water Sampling at the Ambrosia Lake - Phillips Mill Site (Ref. 12, 26, 27, 28, 29, 30) .

Aquifer Sampled		Alluvium			Tres Hermanos-B		
Well Sampled		MW-675			MW-678		
ANALYTE	EPA MCLs/NMWQCC Ground Water Standards	2001	2004	2007	2001	2004	2007
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Uranium***	0.03/0.03	**3.17**	**1.10**	**0.27**	**0.07**	**0.057**	**0.053**
Selenium***	0.01*/0.05	**0.43**	**0.66**	**0.86**	**0.17**	**0.230**	**0.12**
Molybdenum***	0.1*/1.0**	**3.92**	**0.60**	**0.12**	0.023	0.012	0.006
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Sulfate	250/600	**4,040**	**3,200**	**3,200**	**7,340**	**6,800**	**8,200**
Nitrate	10/10	**42**	**50**	**66**	**479**	**520**	**390**
	s.u.	s.u.	s.u.	s.u.	s.u.	s.u.	s.u.
pH	6.00 - 9.00	6.72	7.02	7.51	7.26	7.29	7.24
	uOhms/cm	uOhms/cm	uOhms/cm	uOhms/cm	uOhms/cm	uOhms/cm	uOhms/cm
Specific Cond.	NS	7,000	6,555	5660	14,280	13,580	14,318

Legend:
* 40 CFR Part 192 Subpart A, Table 1. Maximum Concentration of Constituents for Ground Water Protection.
** Irrigation Standard
*** Results for metals are in the dissolved phase.
Nitrate = Nitrate + Nitrite as Nitrogen
Bold results are above standards.
NS – No Standard
MCL - Maximum Contaminant Level.
NMWQCC - New Mexico Water Quality Control Commission.
mg/L - milligrams per Liter.
s.u. - standard units.
uOhms/cm - mirco ohms per centimeter.

REFERENCES

1-4

federal register

Friday
December 14, 1990

Part II

Environmental Protection Agency

40 CFR Part 300
Hazard Ranking System; Final Rule

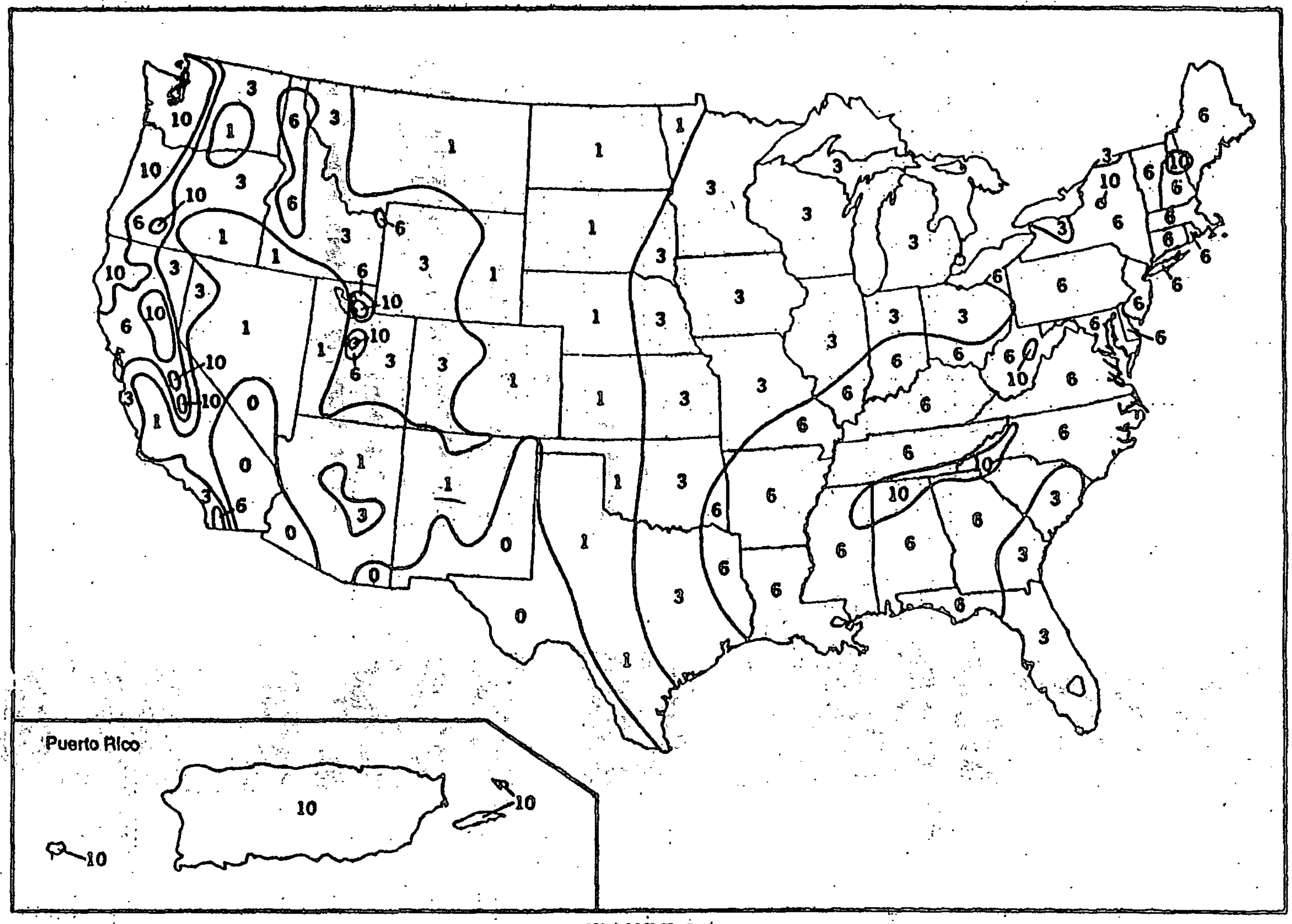


FIGURE 3-2
NET PRECIPITATION FACTOR VALUES

–When measured monthly evapotranspiration is not available, calculate monthly potential evapotranspiration (E_i) as follows:

$$E_i = 0.6\, F_i\, (10\, T_i/I)^a$$

where:

E_i=Monthly potential evapotranspiration (inches) for month i.

F_i=Monthly latitude adjusting value for month i.

T_i=Mean monthly temperature (°C) for month i.

$$I = \sum_{i=1}^{12} (T_i/5)^{1.514}$$

$$a = 6.75\times10^{-7} I^3 - 7.71\times10^{-5} I^2 + 1.79\times10^{-2} I + 0.49239$$

Select the latitude adjusting value for each month from Table 3–3. For latitudes lower than 50° North or 20° South, determine the monthly latitude adjusting value by interpolation.

◦ Calculate monthly net precipitation by subtracting monthly evapotranspiration (or monthly potential evapotranspiration) from monthly precipitation. If evapotranspiration (or potential evapotranspiration) exceeds precipitation for a month, assign that month a net precipitation value of 0.

◦ Calculate the annual net precipitation by summing the monthly net precipitation values.

• Based on the annual net precipitation, assign a net precipitation factor value from Table 3–4.

Enter the value assigned from Figure 3–2 or from Table 3–4, as appropriate, in Table 3–1.

TABLE 3–3.—MONTHLY LATITUDE ADJUSTING VALUES[a]

Latitude[b] (degrees)	Month											
	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
≥50 N	0.74	0.78	1.02	1.15	1.33	1.36	1.37	1.25	1.06	0.92	0.76	0.70
45 N	0.80	0.81	1.02	1.13	1.28	1.29	1.31	1.21	1.04	0.94	0.79	0.75
40 N	0.84	0.83	1.03	1.11	1.24	1.25	1.27	1.18	1.04	0.96	0.83	0.81
35 N	0.87	0.85	1.03	1.09	1.21	1.21	1.23	1.16	1.03	0.97	0.89	0.85
30 N	0.90	0.87	1.03	1.08	1.18	1.17	1.20	1.14	1.03	0.98	0.89	0.88
20 N	0.95	0.90	1.03	1.05	1.13	1.11	1.14	1.11	1.02	1.00	0.93	0.94
10 N	1.00	0.91	1.03	1.03	1.08	1.06	1.08	1.07	1.02	1.02	0.98	0.99
0	1.04	0.94	1.04	1.01	1.04	1.01	1.04	1.04	1.01	1.04	1.01	1.04
10 S	1.08	0.97	1.05	0.99	1.00	0.96	1.00	1.02	1.00	1.06	1.05	1.09
20 S	1.14	0.99	1.05	0.97	0.96	0.91	0.95	0.99	1.00	1.08	1.09	1.15

[a] Do not round to nearest integer.
[b] For unlisted latitudes lower than 50° North or 20° South, determine the latitude adjusting value by interpolation.

TABLE 3–4.—NET PRECIPITATION FACTOR VALUES

Net precipitation (inches)	Assigned value
0	0
Greater than 0 to 5	1
Greater than 5 to 15	3
Greater than 15 to 30	6
Greater than 30	10

3.1.2.3 *Depth to aquifer*. Evaluate depth to aquifer by determining the depth from the lowest known point of hazardous substances at a site to the top of the aquifer being evaluated, considering all layers in that interval. Measure the depth to an aquifer as the distance from the surface to the top of the aquifer minus the distance from the surface to the lowest known point of hazardous substances eligible to be evaluated for that aquifer. In evaluating depth to aquifer in karst terrain, assign a thickness of 0 feet to a karst aquifer that underlies any portion of the sources at the site. Based on the calculated depth, assign a value from Table 3–5 to the depth to aquifer factor.

Determine the depth to aquifer only at locations within 2 miles of the sources at the site, except: if observed ground water contamination attributable to sources at the site extends more than 2 miles beyond these sources, use any location within the limits of this observed ground water contamination when evaluating the depth to aquifer factor for any aquifer that does not have an observed release. If the necessary geologic information is available at multiple locations, calculate the depth to aquifer at each location. Use the location having the smallest depth to assign the factor value. Enter this value in Table 3–1.

TABLE 3–5.—DEPTH TO AQUIFER FACTOR VALUES

Depth to aquifer[a] (feet)	Assigned value
Less than or equal to 25	5
Greater than 25 to 250	3
Greater than 250	1

[a] Use depth of all layers between the hazardous substances and aquifer. Assign a thickness of 0 feet to any karst aquifer that underlies any portion of the sources at the site.

3.1.2.4 *Travel time*. Evaluate the travel time factor based on the geologic materials in the interval between the lowest known point of hazardous substances at the site and the top of the aquifer being evaluated. Assign a value to the travel time factor as follows:

• If the depth to aquifer (see section 3.1.2.3) is 10 feet or less, assign a value of 35.

• If, for the interval being evaluated, all layers that underlie a portion of the sources at the site are karst, assign a value of 35.

• Otherwise:

–Select the lowest hydraulic conductivity layer(s) from within the above interval. Consider only layers at least 3 feet thick. However, do not consider layers or portions of layers within the first 10 feet of the depth to the aquifer.

–Determine hydraulic conductivities for individual layers from Table 3–6 or from in-situ or laboratory tests. Use representative, measured, hydraulic conductivity values whenever available.

–If more than one layer has the same lowest hydraulic conductivity, include all such layers and sum their thicknesses. Assign a thickness of 0 feet to a karst layer that underlies any portion of the sources at the site.

–Assign a value from Table 3–7 to the travel time factor, based on the thickness and hydraulic conductivity of the lowest hydraulic conductivity layer(s).

SUPERFUND CHEMICAL DATA MATRIX METHODOLOGY

Prepared For EPA
January 2004

TABLE OF CONTENTS

APPENDICES

List of Figures

List of Tables

, New Mexico
Phillips Mill
Ambrosia Lake Road
© 2008 Tele Atlas
Image © 2008 TerraMetrics
©2007 Google
Pointer lat 35.402068° lon -107.805361° elev 6956 ft
Streaming ||||||||| 100%
Eye alt 20870 ft

DOE/AL/62350-211
REV. 1

United States Department of Energy

LONG-TERM SURVEILLANCE PLAN FOR THE AMBROSIA LAKE, NEW MEXICO DISPOSAL SITE

RECEIVED
NOV 0 5 1996
OSTI

July 1996

Uranium Mill Tailings Remedial Action Project

INTENDED FOR PUBLIC RELEASE

This report has been reproduced from the best available copy. Available in paper copy and microfiche

Number of pages in this report: 128

DOE and DOE contractors can obtain copies of this report from:

Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
(615) 576-8401

This report is publicly available from:

National Technical Information Service
Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DOE/AL/62350-211
REV. 1

LONG-TERM SURVEILLANCE PLAN FOR THE AMBROSIA LAKE, NEW MEXICO DISPOSAL SITE

July 1996

Prepared for
U.S. Department of Energy
Environmental Restoration Division
UMTRA Project Team
Albuquerque, New Mexico

Prepared by
Jacobs Engineering Group Inc.
Albuquerque, New Mexico

TABLE OF CONTENTS

Section **Page**

TABLE OF CONTENTS (Concluded)

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

LIST OF ACRONYMS

Acronym	Definition
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GJPO	Grand Junction Projects Office
LTSP	long-term surveillance plan
MCL	maximum concentration limit
NGVD	National Geodetic Vertical Datum
NRC	U.S. Nuclear Regulatory Commission
QMC	Quivira Mining Company
UMTRA	Uranium Mill Tailings Remedial Action
UMTRCA	Uranium Mill Tailings Radiation Control Act
UNC	United Nuclear Corporation
UPDCC	UMTRA Project Document Control Center

1.0 INTRODUCTION

This long-term surveillance plan (LTSP) for the Uranium Mill Tailings Remedial Action (UMTRA) Project Ambrosia Lake disposal site in McKinley County, New Mexico, describes the U.S. Department of Energy's (DOE) long-term care program for the disposal site. The DOE will carry out this program to ensure that the disposal cell continues to function as designed. This LTSP was prepared as a requirement for acceptance under the U.S. Nuclear Regulatory Commission (NRC) general license for custody and long-term care of residual radioactive materials.

1.1 STATUTORY AND REGULATORY BACKGROUND

Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 (42 USC §7901 *et seq.*) authorized the DOE to perform remedial actions at 24 inactive uranium mill tailings sites to reduce the potential effect on public health from the unstabilized residual radioactive materials in and around the uranium mill tailings sites. Residual radioactive materials are any wastes that the DOE determines to be radioactive, either in the form of tailings resulting from the processing of ores for the extraction of uranium and other valuable constituents of the ores, or in other forms that relate to such processing, such as sludge and captured contaminated water from these sites (60 FR 2854).

In accordance with Section 275 of the Atomic Energy Act (42 USC §2011 *et seq.*) as amended by the UMTRCA, the U.S. Environmental Protection Agency (EPA) has promulgated health and environmental protection standards for residual radioactive material cleanup and disposal in 40 CFR Part 192. These standards were originally promulgated in 1983 (48 FR 602). Portions of the standards covering ground water protection were remanded by the U.S. Court of Appeals for the Tenth Circuit in 1985. The EPA issued replacement ground water standards on 11 January 1995, with publication of a final rule (60 FR 2854).

The NRC has developed regulations for the issuance of a general license for the custody and long-term care of residual radioactive material disposal sites in 10 CFR Part 40. The license is available only to the DOE (or any successor federal agency designated by the President) and has no termination date. The purpose of this general license is to ensure that the UMTRA disposal sites will be cared for in a manner that protects the public health and safety and the environment. The NRC requires the DOE to submit a site-specific LTSP that meets the requirements of 10 CFR §40.27(b) in order for each disposal site to be licensed.

1.2 SITE HISTORY

Phillips Petroleum Company built the Phillips Mill at the Ambrosia Lake site in 1957 and operated it from June 1958 until March 1963 using uranium ore from nearby mines. The mines around the site consisted of vertical shafts to the ore body several hundred feet below the surface. While in operation, the mill processed over 3 million tons (3 million metric tons) of uranium ore. The Phillips Mill used alkaline pressure leach technology to extract uranium from the ore. Uranium leaching occurred in tanks. Drum filters separated uranium from solution and waste was pumped to a nearby tailings pile. Following purchase of the mill by United Nuclear Corporation (UNC), all operations were scaled back and milling ceased in April 1963. UNC used portions of the mill as a resin ion exchange facility to extract uranium from mine water until 1982 when all site operations ceased.

During the 5-year operational period, the Phillips Mill produced about 3.0 million tons (2.7 million metric tons) of tailings. Some 0.40 million tons (0.36 million metric tons) of tailings were subsequently used to backfill the former Ann Lee Mine No. 1, which is located just outside the disposal site's north boundary (Plate 1).

The Ambrosia Lake uranium mill tailings site was one of the 24 sites identified for remediation in the UMTRCA. The DOE and the state of New Mexico entered into a cooperative agreement under the UMTRCA, establishing terms and conditions of the remedial action (DOE, 1985). The DOE evaluated the environmental impacts associated with the Ambrosia Lake site remedial action in an environmental assessment (DOE, 1987). The NRC and the state of New Mexico concurred with the DOE's remedial action plan (DOE, 1991) to comply with the requirements of 40 CFR Part 192, Subparts A-C.

The DOE conducted surface remedial action at the Ambrosia Lake site in two phases. Remedial action began in 1987 with site preparation followed by asbestos removal and demolition of the former mill buildings and processing facilities. After a hiatus of several years, remedial action resumed: In 1992, 2.7 million cubic yards (yd^3) (2.1 million cubic meters[m^3]) of relocated tailings, contaminated demolition debris and contaminated windblown material were consolidated with 2.4 million yd^3 (1.9 million m^3) of tailings that were stabilized in place (MK-F, 1995). Remedial action that consolidated tailings and contaminated materials, placed them in a disposal cell, and covered them with a radon/infiltration barrier and an erosion protection layer, was completed in June 1995.

The UMTRA Remedial Action Contractor has prepared a completion report documenting compliance with the remedial action plan and the site as-built conditions (MK-F, 1995). The DOE will prepare a final audit report and certification summary and submit it along with the completion report to the NRC for concurrence. Concurrence from the NRC on the certification report will be included (when received) in Attachment 1 of this LTSP.

The DOE also is required to demonstrate compliance with 40 CFR Part 192, Subparts B and C, as revised by 60 FR 2854, for cleanup of existing ground water contamination. The DOE UMTRA Ground Water Project will address the need for remedial action involving residual ground water contamination at the

Ambrosia Lake site. The DOE's final determination will be made in a separate National Environmental Policy Act (42 USC §4321 *et seq.*) document.

1.3 SITE ACQUISITION AND LICENSING

The state of New Mexico currently owns the Ambrosia Lake site. The title documentation is being reviewed by the U.S. Army Corps of Engineers prior to accepting transfer of the site to the federal government. Attachment 2 provides a legal description of the Ambrosia Lake disposal site to be conveyed to the DOE for long-term care and ownership. Figure 1.1 shows the final site boundary and identifies ownership of the site and surrounding areas at the time of licensing.

The general license becomes effective when the NRC concurs with the DOE's determination of completion of remedial action at the Ambrosia Lake site, ownership of the site is transferred to the federal government, and the NRC formally accepts this LTSP. After the general license becomes effective for the Ambrosia Lake disposal site, the DOE will transfer responsibility for the long-term surveillance program to its Grand Junction Projects Office (GJPO) in Grand Junction, Colorado. The programmatic transfer will occur within 90 days of NRC notification that the license is in effect.

1.4 LONG-TERM SURVEILLANCE PROGRAM

This LTSP describes the DOE's long-term surveillance program to be implemented at the Ambrosia Lake disposal site to ensure that the disposal site continues to perform as designed. The plan is based on the UMTRA Project long-term surveillance program guidance (DOE, 1992a) and meets the requirements of 10 CFR §40.27(b) by addressing the following:

- Site description and ownership.
- Description of final site conditions.
- Site inspection procedures and personnel.
- Custodial maintenance and corrective actions programs.
- Record keeping and reporting.
- Emergency response.
- Quality assurance.

2.2 DISPOSAL SITE DESCRIPTION

The Ambrosia Lake disposal site is located on approximately 290 acres (ac) (120 hectares [ha]) of land located in the southern half of Section 28, Township 14 North, Range 9 West, New Mexico Principal Meridian (Figure 2.2). Attachment 2 contains the legal description of the disposal site.

The Ambrosia Lake disposal site is roughly rectangular in shape and has an east-west length of about 4200 ft (1300 m) and a north-south width of about 2900 ft (880 m). The tailings and other contaminated materials are covered with a layer of compacted earth to inhibit radon emanation and water infiltration and an outer layer of rock for erosion protection. The perimeter of the disposal site is marked with warning signs, boundary markers, and survey monuments (Section 4.0).

2.3 DISPOSAL SITE ACCESS AND SECURITY

The Ambrosia Lake disposal site can be accessed by automobile on well-maintained highways following these directions:

- From Albuquerque, New Mexico, take Interstate 40 west about 75 mi (120 km) to Exit 79 (Milan/San Mateo/NM 122/NM 605).
- Go right (north) 0.1 mi (0.2 km) to NM 122 (historic U.S. Highway 66), turn left (west) and go 0.1 mi (0.2 km) on NM 122 to NM 605 following signs for Ambrosia Lake (see Figure 13.1).
- Turn right onto NM 605 and travel about 14 mi (22 km) to NM 509.
- From NM 605, turn left onto NM 509 and travel northwest for 4.6 mi (7.4 km).
- Turn right onto an unmarked east-west graded dirt road with power lines along both sides and travel east about 1 mi (1.6 km) to the site, located just past a cattle guard on the road.

The east-west dirt access road parallels the section line between Sections 28 and 33, which forms the south boundary of the disposal site (Figure 2.2). Presently, entry to the disposal site is restricted only by means of warning signs; there is no fence around the perimeter of the site. However, the access road is privately owned by Quivira Mining Company (QMC). While QMC has granted the DOE permission to use the road, QMC should be notified prior to visiting the site. QMC has indicated that it may close the access road at NM 509 with a gate, at which time the GJPO will obtain a key from QMC. In addition, permission to access the site shall be obtained from either the DOE UMTRA Team Site Manager or the GJPO Supervisory General Engineer (Table 2.1).

Table 2.1 Ambrosia Lake disposal site access contacts

Title of contact	Telephone	Address
DOE UMTRA Team Site Manager	505-845-4022	U.S. Department of Energy Albuquerque Operations Office Environmental Restoration Division Post Office Box 5400 Albuquerque, NM 87115
Supervisory General Engineer	970-248-6006	U.S. Department of Energy Grand Junction Projects Office 2597 B 3/4 Road Grand Junction, CO 81503

The effectiveness of site security measures will be monitored through scheduled site inspections (Section 6.0). A DOE 24-hour telephone number on the entrance sign (Section 4.0) and agreements with local agencies to notify the DOE in the event of an emergency or breach of site integrity (Section 11.0) serve as additional security measures. Because of the remote location of the disposal site, purposeful intrusion is not expected; however, if intrusion, vandalism, or other factors become a problem, site security will be reevaluated.

2.4 DISPOSAL CELL DESIGN

The disposal cell is located on a low-gradient alluvial slope upland from the main active valley stream channel. Erosion processes operating in the active channel will not conceivably affect the tailings pile within the projected stabilization life of 1000 years. The site is also at a great enough distance from nearby mesas to preclude any hazard from slope failure processes such as landslides, debris flows, mud flows, and rockfalls. The geomorphic processes posing a potential hazard to the stabilized site are ephemeral drainage channel changes, low-gradient slope erosion, and wind erosion.

The stabilized disposal cell was constructed above the ground surface; it contains 6.9 million dry tons (6.3 million metric tons), and approximately 5.2 million yd^3 (3.9 million m^3) of tailings and contaminated soil and debris. The disposal cell is roughly rectangular with a maximum length of approximately 2500 ft (760 m) and a maximum width of about 1600 ft (490 m) including the toe apron (Plate 1). The disposal cell rises to a maximum height of approximately 50 ft (15 m) above the surrounding terrain.

The main tailings pile was stabilized in place. Relocated contaminated materials were placed on top of the tailings and then covered with a radon/infiltration barrier. The topslopes and sideslopes of the disposal cell were capped with rock to prevent wind and water erosion of the underlying radon/infiltration barrier and tailings.

A 30-inch (80-cm)-thick radon/infiltration barrier was placed over the contaminated materials. This barrier was constructed of clayey soil and is designed to reduce the radon-222 flux from the disposal cell to less than 20 picocuries per square meter per second and minimize the rate of surface water infiltration into the tailings. The thickness of the radon/infiltration barrier, in conjunction with the erosion protection layer, will prevent the disposal cell from being adversely affected by freezing and thawing cycles.

The erosion protection layer is 6-inch (15-cm)-thick riprap on the topslopes and 12-inch (30-cm)-thick riprap on the sideslopes. The topslopes have Type A riprap with a rock diameter of predominately 2-3 inches (5-8 cm); the sideslopes have Type B riprap with a rock diameter of predominately 4-6 inches (10-15 cm). A 6-inch (15-cm)-thick bedding layer was placed between the riprap and the radon/infiltration barrier to prevent damage to the barrier by rocks and loss of the fined-grained radon/infiltration barrier material. The maximum grade is 4 percent on the topslopes and 20 percent on the sideslopes. These grades, in conjunction with the bedding layer, will allow excess surface water to run off the disposal cell. The components of both the topslope and sideslope covers are intended to minimize the potential for deep percolation of precipitation into the residual radioactive material.

At the toe of the disposal cell there is a rock apron, varying in thickness from 34 inches (86 cm) to 66 inches (170 cm) and primarily constructed of Type C riprap with a rock diameter of predominately 10-12 inches (25-30 cm). At the ground surface, riprap protection extends up to 40 ft (12 m) from the toe of the disposal cell.

2.5 DESCRIPTION OF ADJACENT AREAS

The conditions of several features immediately adjacent to the disposal cell or on private property bordering the disposal site are important to note because changes associated with the features may need to be monitored during site inspections. These features are identified on Plate 1.

In the northeast corner of the disposal site there is a landfill pit containing nonradiological and slightly contaminated demolition debris from the processing site (MK-F, 1995). The debris pit is distinguishable only by a slight mound; the pit area was reseeded and mulched.

Three vent shafts to underground mining areas are located in the immediate site area. One is located just inside the north-central boundary of the disposal site. This shaft, which was sealed by UNC prior to start of remedial action, has a spot-welded cover. Another on-site shaft, which has a bolted-on cover, is near the southwest corner of the site. The third vent shaft, which also has a bolted-on cover, is located on QMC property just outside the southwest corner of the site.

2.0 FINAL SITE CONDITIONS

Remedial action at the Ambrosia Lake site consisted of stabilizing the majority of the tailings in place. Contaminated demolition debris from the former mill and soil from surrounding areas that was contaminated with windblown tailings were also cleaned up. A rock-covered disposal cell was constructed in the southwestern portion of the designated processing site to control the residual radioactive material in accordance with 40 CFR Part 192. The Ambrosia Lake disposal site is unfenced, but its perimeter is marked with warning signs. The site completion report (MK-F, 1995) contains a detailed description of the final site conditions.

2.1 DESCRIPTION OF THE DISPOSAL SITE VICINITY

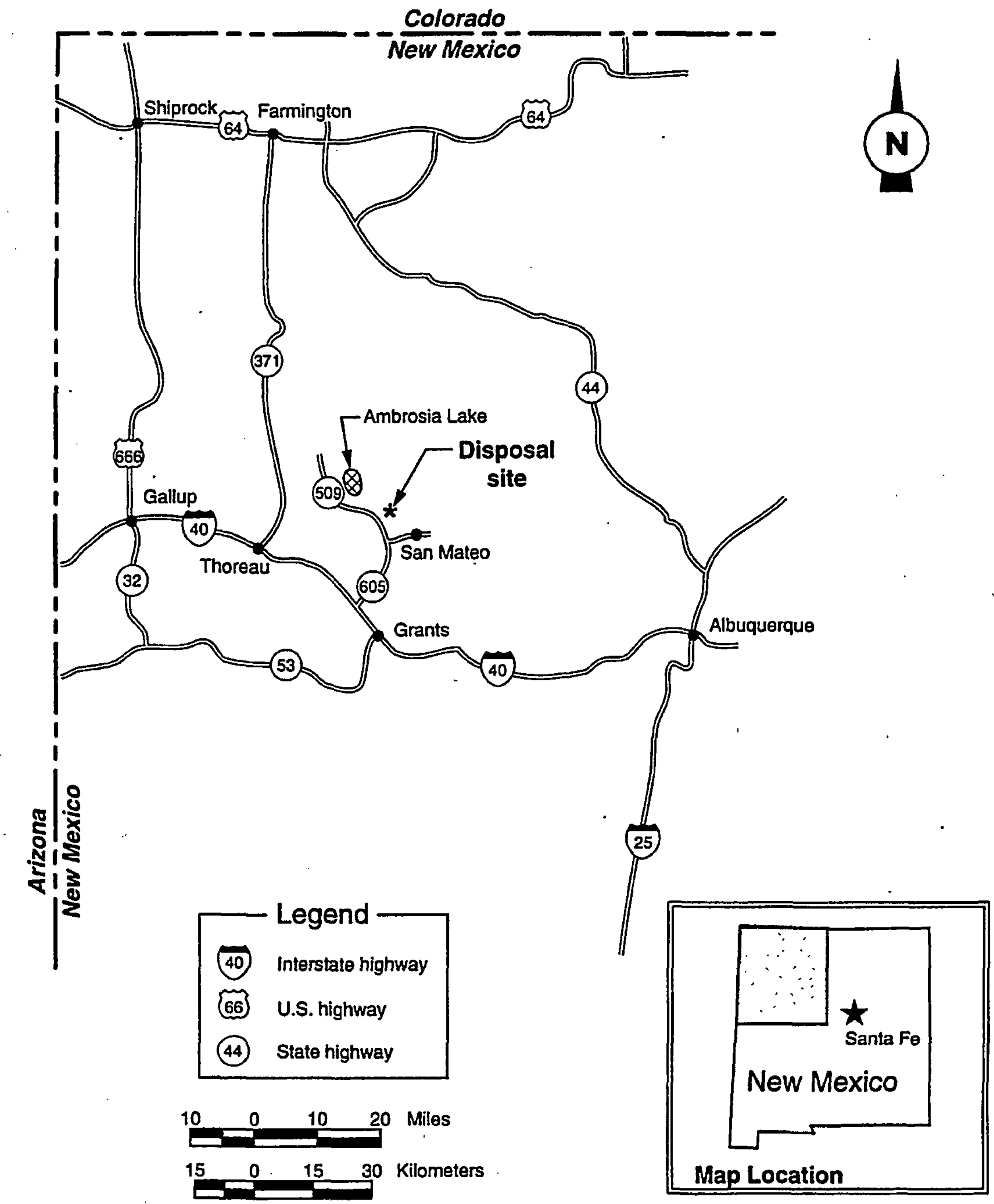
The Ambrosia Lake disposal site is in McKinley County in northwest New Mexico. The site is approximately 25 miles (mi) (40 kilometers [km]) north of Grants, New Mexico, accessible via state highways (Figure 2.1).

The disposal site is situated in the Ambrosia Lake Valley, on the southern edge of the San Juan Basin portion of the Colorado Plateau, at an elevation of about 7000 feet (ft) (2100 meters [m]) National Geodetic Vertical Datum (NGVD). The topography of the area surrounding the site consists of a broad valley trending northwest to southeast bounded by elongated mesas that rise to an elevation of about 8000 ft (2400 m) NGVD. Several small ephemeral streams and channels originating in the canyons to the northeast direct the surface run-off in the immediate area to the southwest. The site lies within the drainage basin of the Arroyo del Puerto, an intermittent stream about 1.0 mi (1.6 km) southwest of the site. The Arroyo del Puerto flows into San Mateo Creek about 5 mi (8 km) south of the site. There are no perennial streams in the vicinity of the Ambrosia Lake disposal site.

The valley has a semiarid climate characterized by low precipitation, abundant sunshine, low relative humidity, and large diurnal and annual temperature ranges (DOE, 1991). Annual precipitation is about 9 inches (20 centimeters [cm]). Normally over one-half of the annual precipitation occurs from July to September, usually during brief, intense thunderstorms. Annual lake evaporation is estimated to be 54 in (140 cm) for the region. Temperatures range from below 0 degrees Fahrenheit (°F) (-20 degrees Celsius[°C]) in the winter to over 100 °F (40 °C) in the summer. Winds average about 6 mi (10 km) per hour and are predominately from the west and north-northwest.

Over the last decade, surface use of the land in the vicinity of the Ambrosia Lake site has shifted from uranium mining and milling to livestock grazing. Other potential future surface uses include pasture cultivation.

Figure 2.1
Location Map, Ambrosia Lake, New Mexico, Site



MAC: SITE/AMB/LTSP/SITELOC

2.2 DISPOSAL SITE DESCRIPTION

The Ambrosia Lake disposal site is located on approximately 290 acres (ac) (120 hectares [ha]) of land located in the southern half of Section 28, Township 14 North, Range 9 West, New Mexico Principal Meridian (Figure 2.2). Attachment 2 contains the legal description of the disposal site.

The Ambrosia Lake disposal site is roughly rectangular in shape and has an east-west length of about 4200 ft (1300 m) and a north-south width of about 2900 ft (880 m). The tailings and other contaminated materials are covered with a layer of compacted earth to inhibit radon emanation and water infiltration and an outer layer of rock for erosion protection. The perimeter of the disposal site is marked with warning signs, boundary markers, and survey monuments (Section 4.0).

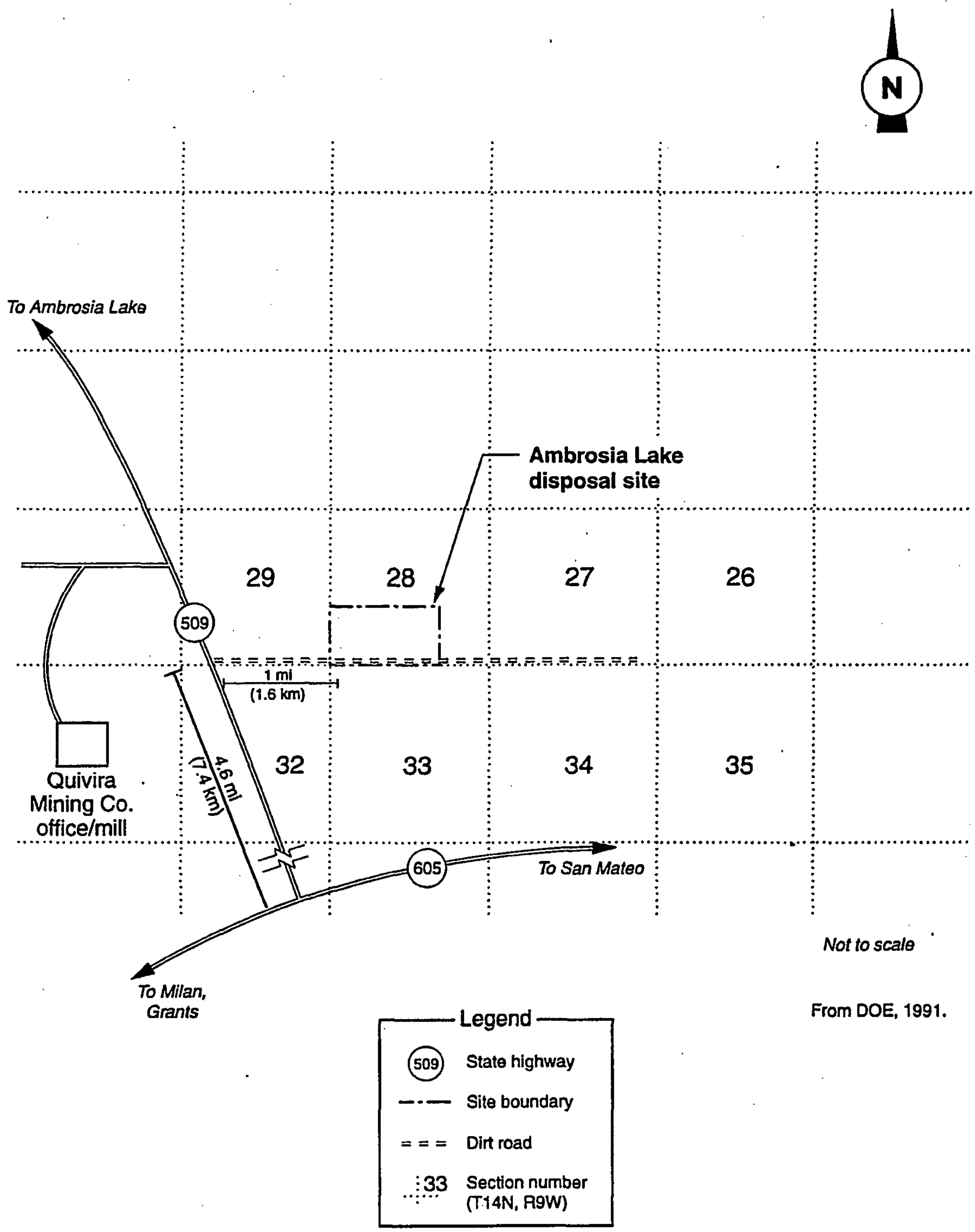
2.3 DISPOSAL SITE ACCESS AND SECURITY

The Ambrosia Lake disposal site can be accessed by automobile on well-maintained highways following these directions:

- From Albuquerque, New Mexico, take Interstate 40 west about 75 mi (120 km) to Exit 79 (Milan/San Mateo/NM 122/NM 605).
- Go right (north) 0.1 mi (0.2 km) to NM 122 (historic U.S. Highway 66), turn left (west) and go 0.1 mi (0.2 km) on NM 122 to NM 605 following signs for Ambrosia Lake (see Figure 13.1).
- Turn right onto NM 605 and travel about 14 mi (22 km) to NM 509.
- From NM 605, turn left onto NM 509 and travel northwest for 4.6 mi (7.4 km).
- Turn right onto an unmarked east-west graded dirt road with power lines along both sides and travel east about 1 mi (1.6 km) to the site, located just past a cattle guard on the road.

The east-west dirt access road parallels the section line between Sections 28 and 33, which forms the south boundary of the disposal site (Figure 2.2). Presently, entry to the disposal site is restricted only by means of warning signs; there is no fence around the perimeter of the site. However, the access road is privately owned by Quivira Mining Company (QMC). While QMC has granted the DOE permission to use the road, QMC should be notified prior to visiting the site. QMC has indicated that it may close the access road at NM 509 with a gate, at which time the GJPO will obtain a key from QMC. In addition, permission to access the site shall be obtained from either the DOE UMTRA Team Site Manager or the GJPO Supervisory General Engineer (Table 2.1).

Figure 2.2
Vicinity Map, Ambrosia Lake, New Mexico, Site



MAC: SITE/AMBLTSP/LOCAMBLAKE

Table 2.1 Ambrosia Lake disposal site access contacts

Title of contact	Telephone	Address
DOE UMTRA Team Site Manager	505-845-4022	U.S. Department of Energy Albuquerque Operations Office Environmental Restoration Division Post Office Box 5400 Albuquerque, NM 87115
Supervisory General Engineer	970-248-6006	U.S. Department of Energy Grand Junction Projects Office 2597 B 3/4 Road Grand Junction, CO 81503

The effectiveness of site security measures will be monitored through scheduled site inspections (Section 6.0). A DOE 24-hour telephone number on the entrance sign (Section 4.0) and agreements with local agencies to notify the DOE in the event of an emergency or breach of site integrity (Section 11.0) serve as additional security measures. Because of the remote location of the disposal site, purposeful intrusion is not expected; however, if intrusion, vandalism, or other factors become a problem, site security will be reevaluated.

2.4 DISPOSAL CELL DESIGN

The disposal cell is located on a low-gradient alluvial slope upland from the main active valley stream channel. Erosion processes operating in the active channel will not conceivably affect the tailings pile within the projected stabilization life of 1000 years. The site is also at a great enough distance from nearby mesas to preclude any hazard from slope failure processes such as landslides, debris flows, mud flows, and rockfalls. The geomorphic processes posing a potential hazard to the stabilized site are ephemeral drainage channel changes, low-gradient slope erosion, and wind erosion.

The stabilized disposal cell was constructed above the ground surface; it contains 6.9 million dry tons (6.3 million metric tons), and approximately 5.2 million yd^3 (3.9 million m^3) of tailings and contaminated soil and debris. The disposal cell is roughly rectangular with a maximum length of approximately 2500 ft (760 m) and a maximum width of about 1600 ft (490 m) including the toe apron (Plate 1). The disposal cell rises to a maximum height of approximately 50 ft (15 m) above the surrounding terrain.

The main tailings pile was stabilized in place. Relocated contaminated materials were placed on top of the tailings and then covered with a radon/infiltration barrier. The topslopes and sideslopes of the disposal cell were capped with rock to prevent wind and water erosion of the underlying radon/infiltration barrier and tailings.

A 30-inch (80-cm)-thick radon/infiltration barrier was placed over the contaminated materials. This barrier was constructed of clayey soil and is designed to reduce the radon-222 flux from the disposal cell to less than 20 picocuries per square meter per second and minimize the rate of surface water infiltration into the tailings. The thickness of the radon/infiltration barrier, in conjunction with the erosion protection layer, will prevent the disposal cell from being adversely affected by freezing and thawing cycles.

The erosion protection layer is 6-inch (15-cm)-thick riprap on the topslopes and 12-inch (30-cm)-thick riprap on the sideslopes. The topslopes have Type A riprap with a rock diameter of predominately 2-3 inches (5-8 cm); the sideslopes have Type B riprap with a rock diameter of predominately 4-6 inches (10-15 cm). A 6-inch (15-cm)-thick bedding layer was placed between the riprap and the radon/infiltration barrier to prevent damage to the barrier by rocks and loss of the fined-grained radon/infiltration barrier material. The maximum grade is 4 percent on the topslopes and 20 percent on the sideslopes. These grades, in conjunction with the bedding layer, will allow excess surface water to run off the disposal cell. The components of both the topslope and sideslope covers are intended to minimize the potential for deep percolation of precipitation into the residual radioactive material.

At the toe of the disposal cell there is a rock apron, varying in thickness from 34 inches (86 cm) to 66 inches (170 cm) and primarily constructed of Type C riprap with a rock diameter of predominately 10-12 inches (25-30 cm). At the ground surface, riprap protection extends up to 40 ft (12 m) from the toe of the disposal cell.

2.5 DESCRIPTION OF ADJACENT AREAS

The conditions of several features immediately adjacent to the disposal cell or on private property bordering the disposal site are important to note because changes associated with the features may need to be monitored during site inspections. These features are identified on Plate 1.

In the northeast corner of the disposal site there is a landfill pit containing nonradiological and slightly contaminated demolition debris from the processing site (MK-F, 1995). The debris pit is distinguishable only by a slight mound; the pit area was reseeded and mulched.

Three vent shafts to underground mining areas are located in the immediate site area. One is located just inside the north-central boundary of the disposal site. This shaft, which was sealed by UNC prior to start of remedial action, has a spot-welded cover. Another on-site shaft, which has a bolted-on cover, is near the southwest corner of the site. The third vent shaft, which also has a bolted-on cover, is located on QMC property just outside the southwest corner of the site.

The former Ann Lee Mine is located on UNC property just outside the north boundary of the disposal site. The mine shaft is reported to have been backfilled by UNC with mine wastes and dirt and is capped with a concrete slab.

The DOE has revegetated areas of the site surrounding the disposal cell and adjacent areas as part of the remedial action plan and agreements with vicinity property owners (DOE, 1991; MK-F, 1995). Final vegetative cover should equal that of surrounding unremediated areas. These revegetated areas are currently fenced with barbed wire and woven wire fencing to prevent livestock grazing while vegetation is reestablishing. After 5 years, QMC has the option to relocate the fencing to follow the western property boundary of the disposal site (Attachment 2). Agreements with QMC give QMC ownership of the fencing to the south and west of the site and require that QMC maintain the fencing and the cattle guard at the site entrance for 5 years (from 1995) (Charlton, 1993 and 1995; Pommerening, 1992).

3.0 SITE DRAWINGS AND PHOTOGRAPHS

At the completion of remedial action, the UMTRA Remedial Action Contractor documented final disposal site conditions with site maps, as-built drawings, and photographs (MK-F, 1995). This information illustrates baseline conditions for comparison to future disposal site conditions.

All original drawings, site maps, and photographs will become part of the Ambrosia Lake permanent site file and be archived by the UMTRA Project Document Control Center (UPDCC), in Albuquerque, New Mexico. At licensing, the DOE will transfer the site file to the GJPO. *The disposal site maps and drawings may be further modified by the GJPO, as* necessary. The GJPO will be responsible for maintaining the permanent site file and adding any new maps, drawings, and photographs to the site file.

3.1 DISPOSAL SITE BASELINE MAP

The Ambrosia Lake disposal site baseline map (Plate 1) was compiled from the final topographic survey map and as-built drawings of the disposal site area. The final topographic survey was conducted in accordance with the DOE long-term surveillance program guidance (DOE, 1992a). The following specifications were used in developing the topographic map: a scale of 1 inch = 200 ft (1 cm = 24 m), a contour interval of 2 ft (0.6 m), and coverage of the disposal site and an area of 0.25 mi (0.4 km) outside the site perimeter.

In addition to topography, the baseline map defines the following:

- Disposal site property boundaries and access road.
- Outline of the toe and crest of the disposal cell.
- Location of drainage swales.
- Ground water monitor wells.
- Project survey control point.
- Permanent site surveillance features (e.g., monuments, markers, and signs).
- Other on-site features to be inspected (e.g., displacement monuments, vent shafts, debris pit).
- Site grid coordinate system.

When this site map is updated, the revised map will include the year of revision and the revision number. The Ambrosia Lake disposal site map will serve as the baseline map for site inspections.

3.2 DISPOSAL SITE AS-BUILT DRAWINGS

A set of as-built drawings illustrates final disposal cell construction and final disposal site conditions (MK-F, 1995). These drawings may be used to evaluate changes in physical site conditions or the disposal cell over time and to develop corrective action plans, if required.

3.3 SITE BASELINE PHOTOGRAPHS

The photographic record of the Ambrosia Lake disposal site includes a series of aerial and ground photographs that provide a baseline visual record of site construction activities and final site conditions to complement the as-built drawings. The final completion report for the disposal site contains a complete set of photographs that documents each phase of construction (MK-F, 1995). The post-construction photographs provide an orientation tool for site inspections and a baseline record of surveillance features.

A set of aerial photographs was taken of the Ambrosia Lake disposal site in September 1995 after surface remedial action was completed (Table 3.1). These photographs will enable inspectors to monitor changes in large-scale site conditions (e.g., erosion patterns, vegetation changes, and land use) over time. The need for new aerial photographs will be evaluated at 5-year intervals from the effective date of the site license. More detailed information on the aerial photography specifications is provided in the DOE long-term surveillance program guidance (DOE, 1992a) and the Ambrosia Lake site surveillance and maintenance subcontract documents (MK-ES, 1992).

3.4 SITE INSPECTION MAPS AND PHOTOGRAPHS

Site maps will be prepared and site photographs will be taken as part of the long-term surveillance program site inspections (Section 6.5). The GJPO will prepare a site inspection map based on the final site baseline maps and drawings. This inspection map will be updated, as necessary, after each site inspection. Each site inspection map will indicate the year of the inspection and the type of inspection.

Photographs will be taken during disposal site inspections to document conditions at the disposal cell and the disposal site. These photographs will provide a continuous record for monitoring changing conditions over time. The photographs can be compared with the baseline photographs to monitor site features. Each photograph will be recorded individually on a site inspection photo log (Attachment 3). An appropriate description of the feature photographed, including azimuth (if necessary), will be entered into the log.

5.0 GROUND WATER CHARACTERIZATION AND MONITORING

The need for ground water monitoring at the Ambrosia Lake disposal site was evaluated in accordance with the NRC regulations in 10 CFR §40.27(b)(2), and long-term surveillance program guidelines (DOE, 1992a). The implementation guidance in Subpart C of 40 CFR Part 192, as revised by 60 FR 2854, describes specific conditions for applying supplemental standards for ground water rather than meeting background levels or numerical standards. The DOE has determined that a program to monitor ground water is not required for the Ambrosia Lake site because ground water in the uppermost aquifer is of limited use, and a narrative supplemental standard has been applied to the site that does not include numerical concentration limits or a point of compliance. The limited use designation is appropriate because the uppermost aquifer does not represent a ground water resource since the aquifer will not sustain a yield of 150 gallons (gal) (570 liters [L]) per day to wells.

5.1 GROUND WATER CHARACTERIZATION

Ground water at the Ambrosia Lake site is influenced by climate, human activities, and surface and subsurface features. Though the focus of this section is a description of the hydrostratigraphic units that may be affected by the disposal cell, information regarding the physical and environmental conditions is included. Most of the information presented here is described in more detail in the Ambrosia Lake remedial action plan (DOE, 1991) and the site observational work plan (DOE, 1995). Some data has been collected since the completion of the site observational work plan and is also reported in this LTSP.

5.1.1 Climate and surface features

A general description of the site climate and surface features is presented in Section 2.1. The potential for recharge of ground water by infiltration of precipitation is estimated as the precipitation less the evaporation and transpiration of vegetation. Reported evaporation is about six times the reported precipitation (Appendix D of DOE, 1991). The majority of the precipitation occurs during the summer when evaporation and transpiration potentials are high and the soil moisture content is low thus limiting significant infiltration. As a result, recharge to ground water may only occur in the vicinity of surface depressions that are able to trap runoff from a wide area. However, these areas are localized and are not expected to contribute significantly to ground water recharge in the vicinity of the Ambrosia Lake disposal site.

5.1.2 Human activities

The Ambrosia Lake area has served as a mining and milling center from the mid-1950's to the early 1980's, with limited activities extending into the 1990's. Dewatering of subsurface strata to facilitate the construction of vertical mine shafts, followed by horizontal mining to extract uranium ore, affected the pre-existing ground water in several subsurface geologic rock units in the area. The ground water pumped from the mines was used for milling processes or was discharged to retention ponds. The influences from nearby mine and mill operations on ground water in the Ambrosia Lake area are discussed in Sections 5.1.3, 5.1.4, and 5.1.5.

Waste water was produced from the former Phillips Mill at a rate of 1 to 5 tons (0.9 to 4.5 metric tons) for every ton of ore processed (Merritt, 1971); therefore, 3 to 15 million tons (2.7 to 13.6 million metric tons) of waste water were produced during the 5 years of ore milling. This is equivalent to between 2200 to 11,000 ac-ft (2.7 to 14 million m^3) of waste water. Waste water, with the tailings, was disposed of in the tailings pile and also collected in two former holding ponds located east of the tailings pile in the southeast corner quarter of Section 28; some waste water was possibly discharged to a canal that led to a separate holding pond called the Voght Tank, formerly located in Section 34; and some waste water also was discharged to two holding ponds near the southeast corner of the tailings pile in Section 33 (Figure 2.2). The influences of these waste water discharges on ground water in the immediate vicinity of the disposal site are discussed in Sections 5.1.3, 5.1.4, and 5.1.5.

The ion-exchange process used at the Ambrosia Lake site probably contributed little if any contamination to the site. Water that was passed through the ion-exchange columns was returned to its source (the mines), and not discharged to the land surface. Water applied to the heap leach piles was collected with a drain system for recovery of uranium using the ion-exchange columns.

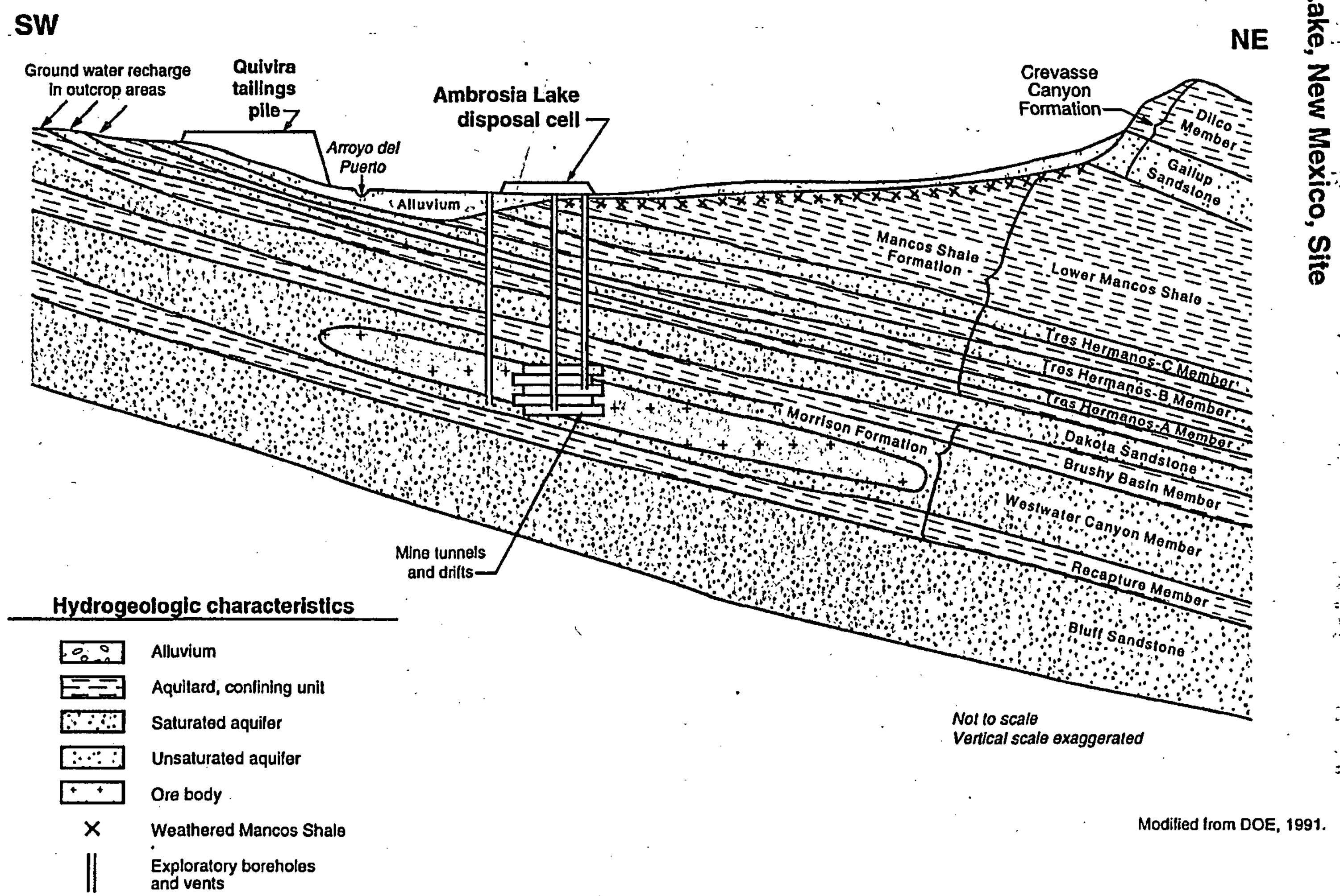
Water supplies associated with mill cleanup activities were from wells completed in the uranium ore zone (the Westwater Canyon Member of the Morrison Formation) and deeper hydrogeologic units. Domestic and stock wells in the Ambrosia Lake area are also completed in the ore zone or deeper units and obtain water at depths from 300 ft (90 m) to greater than 800 ft (240 m). No wells are completed in any of the shallower zones (alluvium and Tres Hermanos Sandstones) within at least a 5-mi (8-km) radius of the site, with the exception of monitor wells installed by the DOE (DOE, 1991). These water supply wells have no impact on the ground water in the uppermost aquifer beneath the disposal site.

The nearest public water supply is operated by the town of San Mateo, 10 mi (16 km) southeast of the Ambrosia Lake site. The water for San Mateo is derived from the Point Lookout Sandstone (Brod, 1979), which is stratigraphically higher than, and not connected with, any of the geologic units at the Ambrosia Lake site, and, therefore, is not impacted by ground water beneath the disposal site.

5.1.3 Hydrostratigraphy

A generalized, regional geologic cross section illustrating the dip, relative depths, and relative thickness of each unit described below is shown in Figure 5.1.

Figure 5.1
Generalized Regional Geologic Cross Section
Ambrosia Lake, New Mexico, Site



Modified from DOE, 1991.

MAC: SITE/AMB/LTSP/GENGOSECT

The soil and rock units underlying the Ambrosia Lake site can be divided into four hydrostratigraphic units. These units, in descending order, include:

1. The alluvium, weathered portions of the Mancos Shale, and the Tres Hermanos-C_1 and -C_2 Sandstone units combined, designated as the uppermost aquifer (DOE, 1991)

2. The Tres Hermanos-B and -A Sandstone units

3. The Dakota Sandstone

4. The Westwater Canyon Member of the Morrison Formation

At the Ambrosia Lake site, Quaternary alluvium lies on top of an erosional surface of weathered Cretaceous Mancos Shale. The alluvium and weathered Mancos Shale are hydraulically interconnected and appear to behave as a single hydrologic unit. Underlying the alluvium/weathered Mancos Shale is the unweathered, lower portion of the Mancos Shale Formation that contains four silty sandstone interbeds, known as the Tres Hermanos-C_1 (upper), and -C_2 (lower), -B, and -A Sandstone units. Other hydrostratigraphic units beneath the site that may be water-bearing include (in descending order) the Cretaceous Dakota Formation and the Jurassic Westwater Canyon Member of the Morrison Formation. Below the Westwater Canyon Member is more than 150 ft (46 m) of shale, siltstone, and sandstone of the Recapture Member of the Morrison Formation, which was not disturbed during uranium mining and acts as a confining layer.

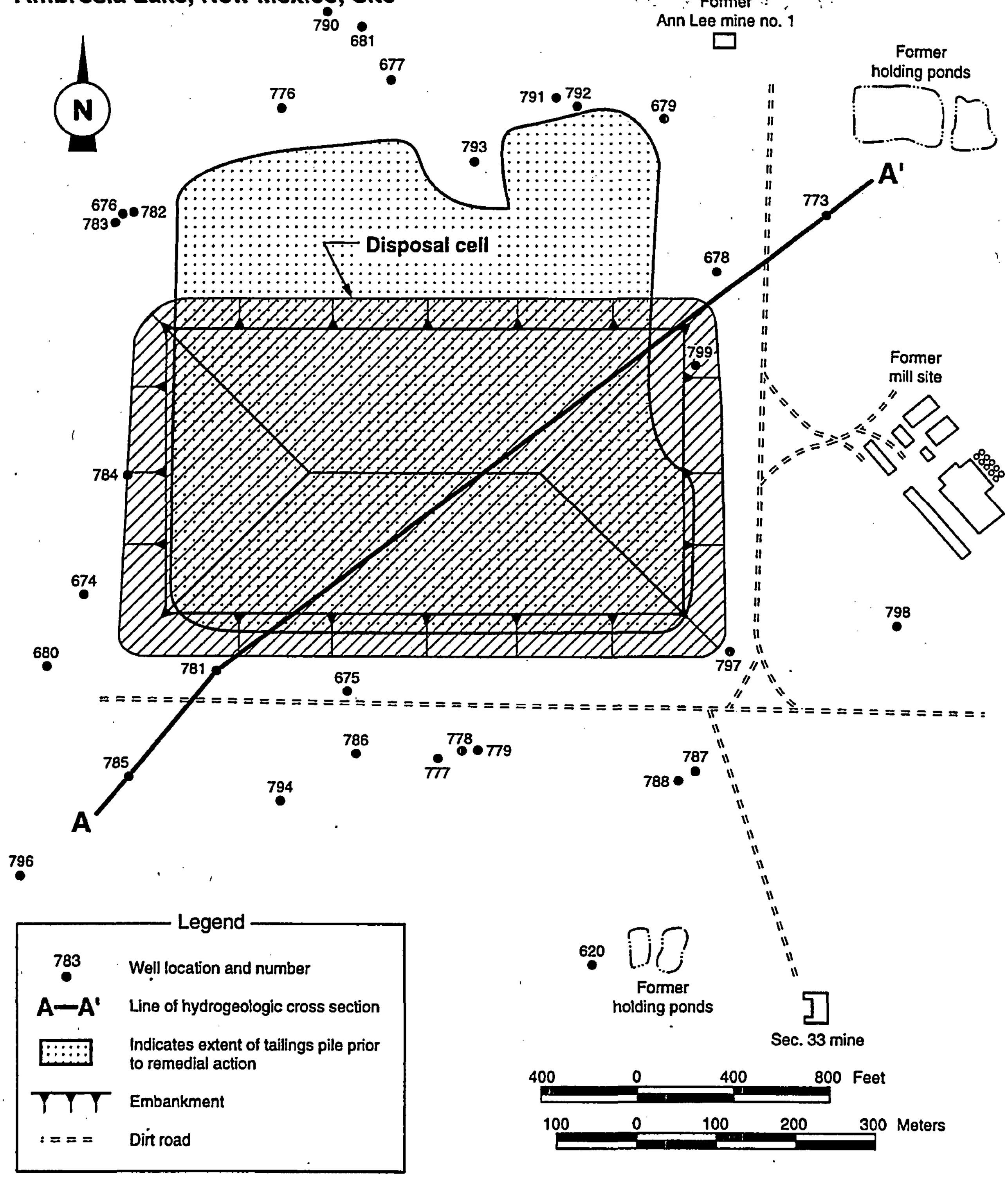
With the exception of the alluvium, the regional dip of the geologic units beneath the site is toward the northeast at approximately 2 degrees. The alluvium has been deposited nearly horizontally on top of the Mancos Shale.

Figure 5.2 shows the location of a cross section constructed using information from monitor wells installed as part of the UMTRA Project. The cross section is shown in Figure 5.3, and illustrates the configuration of the shallow hydrostratigraphic units that lie beneath Ambrosia Lake site. Figure 5.4 shows the relationship between the geologic and hydrostratigraphic units. A summary of the hydraulic properties of these hydrostratigaphic units is presented in Table 5.1.

<u>Alluvium/weathered Mancos Shale and Tres Hermanos-C Sandstone</u>

The alluvium/weathered Mancos Shale unit underlying the Ambrosia Lake site extends to a depth of approximately 15 to 75 ft (5 to 23 m) below ground surface. The alluvium consists of a mixture of gravels, sands, silts, and clays. The alluvium is deposited on top of an erosional surface of weathered Mancos Shale. Underlying the weathered Mancos Shale is the unweathered, lower portion of the Mancos Shale which contains four silty sandstone interbeds,

Figure 5.2
Location of Monitor Wells and Former/Current Site Features
Ambrosia Lake, New Mexico, Site



Modified from DOE, 1991.

MAC: SITE/AMB/LTSP/BASE/MONWELLLOC

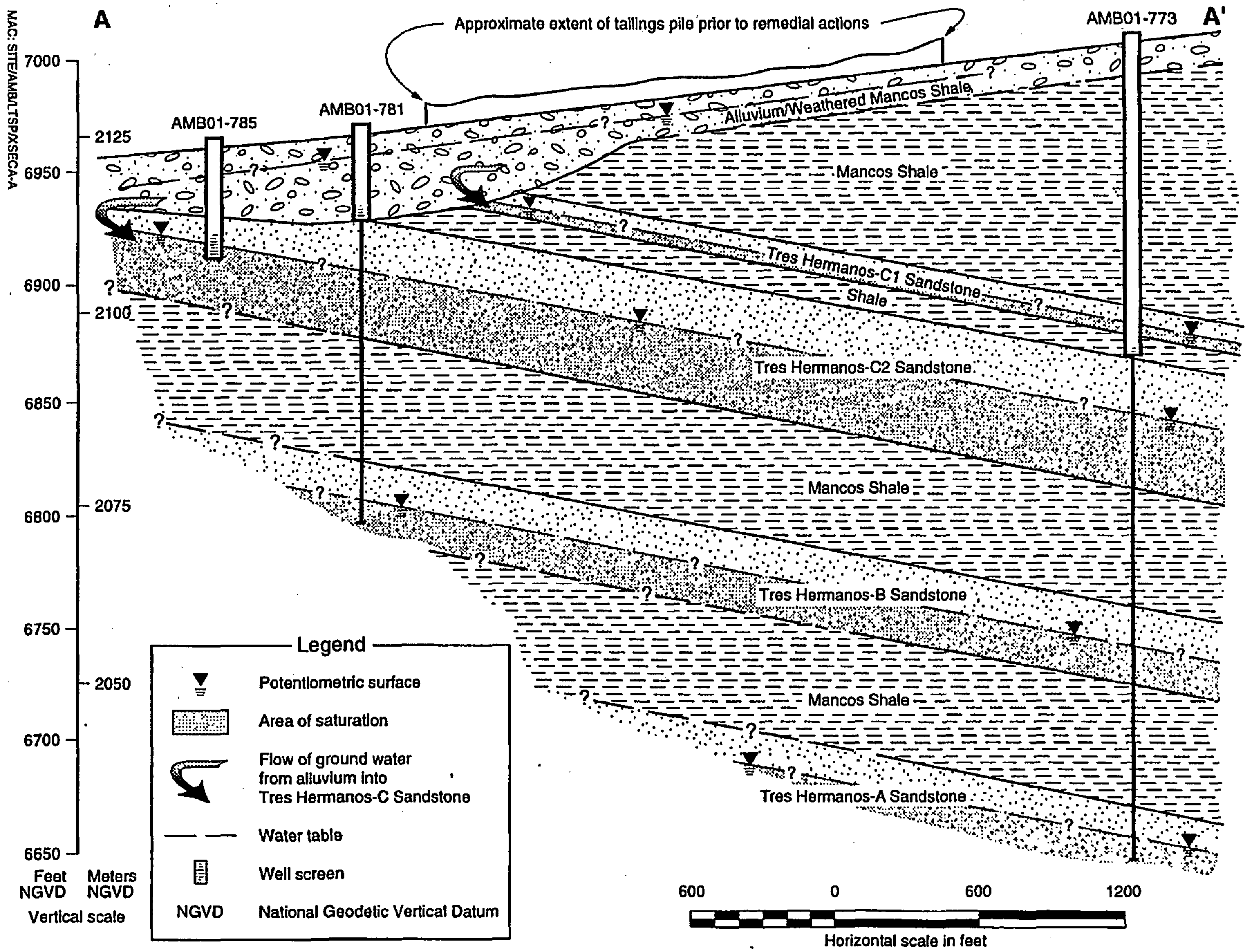
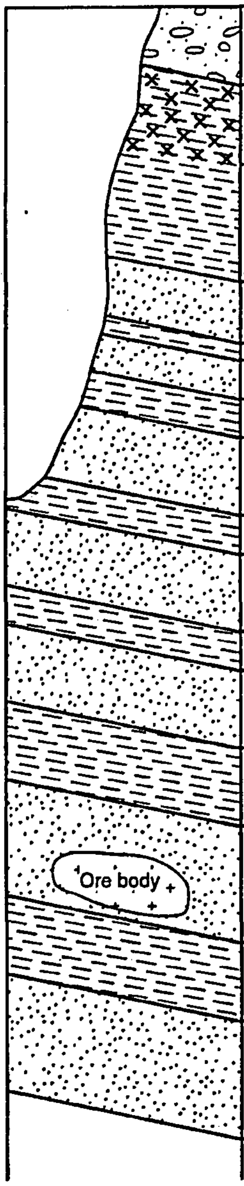


Figure 5.3
Hydrogeologic Cross Section A-A', Ambrosia Lake, New Mexico, Site

Figure 5.4
Relationship Between Geologic and Hydrostratigraphic Units
Ambrosia Lake, New Mexico, Site



Lithology	Hydrostratigraphic Unit	Formation/Member	
Alluvium, clay, silt, sand, and gravel	Alluvium, Weathered Mancos Shale, C_1 C_2 Tres Hermanos Member		
Weathered shale		Mancos Shale	Lower Mancos Shale
Unweathered shale			
C_1 sandstone			Tres Hermanos C
Shale			
C_2 sandstone			
Shale	Boundary		Unnamed
Sandstone	Tres Hermanos A and B		Tres Hermanos B
Shale			Unnamed
Sandstone			Tres Hermanos A
Shale	Boundary		Unnamed
Sandstone	Dakota Sandstone	Dakota Sandstone	
Shale	Boundary	Morrison Formation	Brushy Basin Member
Sandstone	Westwater Canyon		Westwater Canyon Member
Shale	Boundary		Recapture Member
Sandstone	Bluff Sandstone	Bluff Sandstone	

MAC: SITE/AMB/LTSP/HYDRO

Table 5.1 Summary of hydraulic properties of hydrostratigraphic units at the Ambrosia Lake, New Mexico, site

Hydro-stratigraphic unit	Geologic unit formation/member	Lithology	Depth to top of unit in boring at well 680 (ft bgs)	Thickness of units at well 680 (ft)	Porosity (percent)	Approximate saturated thickness (ft) Well No.	1989	1995	Hydraulic conductivity (cm/s)	Typical yield (gpm)	TDS (mg/L)
Alluvium/Weathered Mancos Shale	Alluvium/Weathered Mancos Shale	Clay, silt, sand and gravel	0	58	13[a]	675	10.8	15.5	8E-05[a]	<5	592-14,000[b]
Boundary	Shale	Shale	58	62[c]	NA	NA	NA	NA	NA	NA	3340[d]
	Tres Hermanos-C_1	Fine marine sandstone	NA		5[a]	778	7.5	7.1	2.5E-04[a,e]	NA	NA
Boundary	Shale	Shale.	NA		NA	NA	NA	NA		NA	NA
	Tres Hermanos-C_2	Fine marine sandstone	NA		5[a]	785	3.2	1.6		NA	NA
Boundary	Shale	Shale	120	30	NA	NA	NA	NA	4.3E-08[a]	NA	NA
	Tres Hermanos-B	Fine marine sandstone	150	7	NA	777	10.5	NM	5E-04[f]	NA	1480-12,700[g]
Boundary	Shale	Shale	157	63	NA	NA	NA	NA	1E-05[g]	NA	NA
	Tres Hermanos-A	Fine marine sandstone	220	7	NA	679	0	24.0	NA	2000 (max)[b]	120-2940[g] 2500-9000[b]
Boundary	Shale	Shale	227	78	NA	NA	NA	NA	NA	NA	NA
Dakota	Dakota	Fine-med. marine sandstone	305	38	10[g]	680	13.2	30.7	5.7E-04[b]	10[d]	310-6270[g] 2500-9000[b]
Brushy Basin	Brushy Basin Member	Mudstone w/ss lenses	343	NA	NA	NA	NA	NA	NA	NA	NA
Westwater	Westwater	Fine-coarse							1E-06[a]		

Table 5.1 Summary of hydraulic properties of hydrostratigraphic units at the Ambrosia Lake, New Mexico, site (Concluded)

Hydro-stratigraphic unit	Geologic unit formation/ member	Lithology	Depth to top of unit in boring at well 680 (ft bgs)	Thickness of units at well 680 (ft)	Porosity (percent)	Approximate saturated thickness (ft)			Hydraulic conductivity (cm/s)	Typical yield (gpm)	TDS (mg/L)
						Well No.	1989	1995			
Canyon	Canyon Member	fluvial sandstone	NA	NA	10[f]	NA	NA	NA	4.3E-04[h]	80-730[d]	360-2200[b]
Recapture	Recapture Member	Siltstone w/sh and ss lenses	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Bluff Sandstone	Fine-medium eolian sandstone	NA	NA	NA	NA	NA	NA	4.7E-07[b]	10[d]	2300[b]

[a]DOE, 1991.
[b]Brod and Stone, 1981.
[c]Combined thickness of Tres Hermanos-C_1, -C_2, and Mancos Shale.
[d]Purtymun et al., 1977.
[e]Combined hydraulic conductivity of Tres Hermanos-C_1 and -C_2 Sandstone units.
[f]Brod, 1979.
[g]Bostick, 1985.
[h]Kelly et al., 1980.

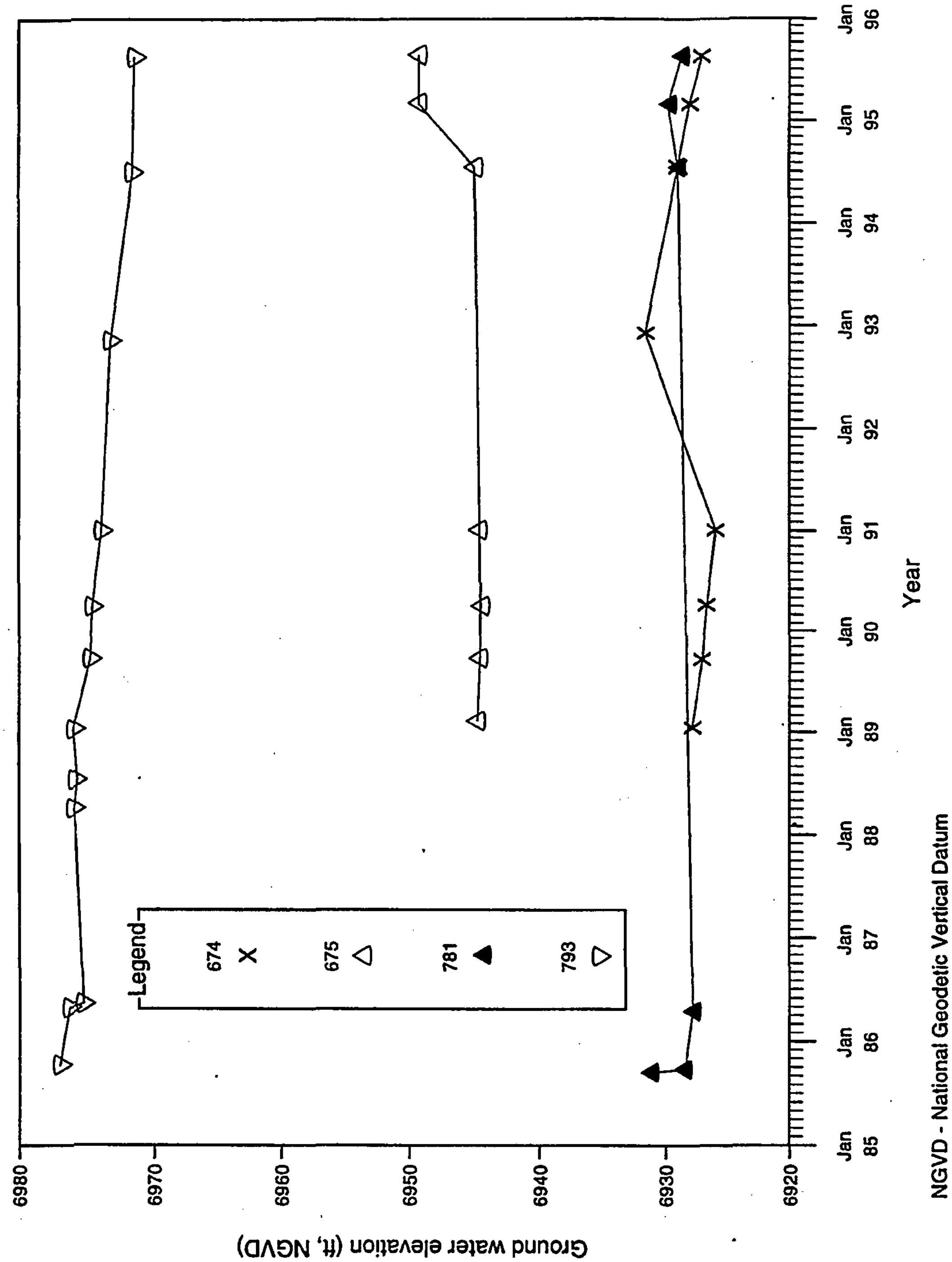
bgs – below ground surface.
cm/s – centimeters per second.
gpm – gallons per minute.
NA – not available.
NM – no ground water elevations were measured.
sh – shale.
ss – sandstone.

known as the Tres Hermanos-C_1 (upper), and -C_2 (lower), -B, and -A Sandstone units. The Tres Hermanos-C_1 and -C_2 Sandstone units are separated by a 10- to 15-ft (3- to 5-m) -thick interbed of shale and subcrop into the alluvium beneath the western side of the site (Figures 5.1 and 5.3). The saturated portions of the alluvium/weathered Mancos Shale unit and the Tres Hermanos-C_1 and -C_2 Sandstone units comprise the uppermost aquifer. Water level observations collected in 1995 indicate that the maximum saturated thickness of any portion of this aquifer is about 25 ft (8 m).

The majority of ground water present in the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone units at the Ambrosia Lake site is most likely a result of past uranium mining and milling activities in the area. During the period of the mill's operation, the discharge of ground water pumped from the Ann Lee Mine, as part of the mine dewatering process, and subsequent infiltration of water from an unlined mill process (makeup) water pond infiltrated into the underlying soil and bedrock including the alluvium/weathered Mancos Shale unit. Ground water to the north of the former tailings pile in the alluvium/weathered Mancos Shale unit appears to flow to the southwest under the site on top of the unweathered Mancos Shale (Figure 5.3). The ground water flows into the Tres Hermanos-C_1 and -C_2 Sandstone units where they subcrop into the overlying alluvium/weathered Mancos Shale unit. Ground water within both the upper and lower Tres-Hermanos-C sandstone units flows to the northeast in the direction of the regional dip as shown in Figure 5.3 (Brod and Stone, 1981).

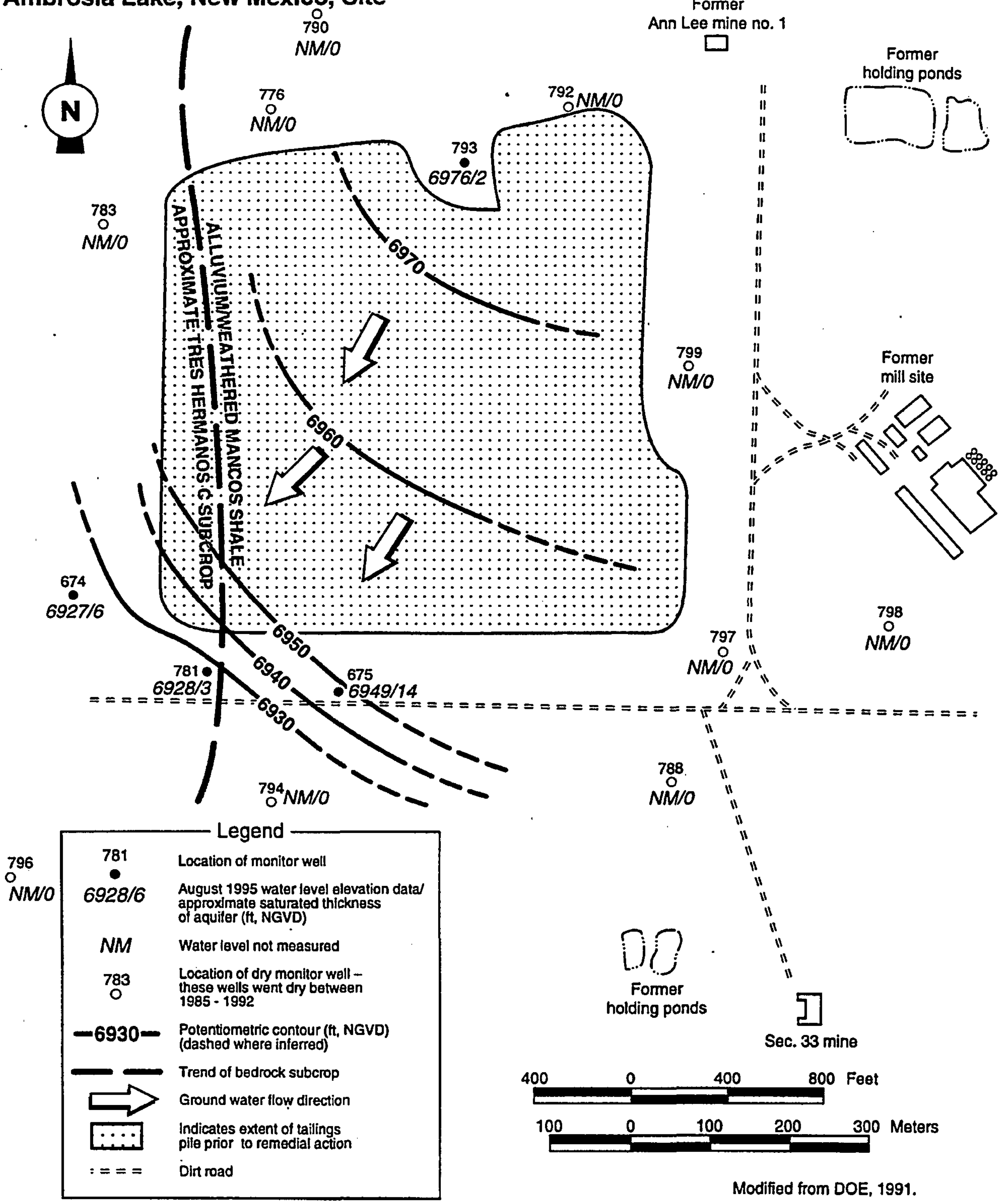
Water level measurements collected in 1995 indicate that perched ground water occurs in the alluvium/weathered Mancos Shale at depths from 15 to 45 ft (5 to 14 m) below ground level at the site. During the period of investigation, the alluvium/weathered Mancos Shale unit was saturated below and directly south and west of the former tailings pile. Little or no ground water was encountered further to the south and west of the site because the Tres Hermanos-C Sandstone units intercept the flow in the alluvium/weathered Mancos Shale unit. Hydrographs of selected water level data collected from monitor wells completed in the alluvium/weathered Mancos Shale unit (AMB01-0674, -0675, -0781, -0793) from 1985 to 1995 are presented in Figure 5.5. Water levels have generally decreased in well 0674 since 1988, and in well 793 since 1993. Water levels have remained relatively constant in well 781 since 1986. However, recent water level rises have occurred in well 0675 which may be the result of toe drain runoff from the recently completed disposal cell. Ground water in the alluvium/weathered Mancos Shale unit flows along the southwestwardly sloping contact of the Mancos Shale under a hydraulic gradient estimated to be 0.025 from observations made in 1995 (Figure 5.6). The average hydraulic conductivity in the alluvium/weathered Mancos Shale unit is approximately 3×10^{-4} cm per second (0.9 ft per day) and the average linear ground water velocity is approximately 7×10^{-5} cm per second (0.2 ft per day) (DOE, 1991). Ground water is present in the alluvium several thousand feet southwest of the site. This ground water is associated with mine dewatering discharges into the Arroyo del Puerto, which is topographically much lower and

Figure 5.5
Hydrograph Showing Ground Water Elevation Trends in Monitor Wells Completed in the Alluvium/Weathered Mancos Shale Hydrostratigraphic Unit Ambrosia Lake, New Mexico, Site



MAC: SITE/AMB/LTSP/HYDRGRPH

Figure 5.6
Ground Water Surface Map for Alluvium/Weathered Mancos Shale
Ambrosia Lake, New Mexico, Site



Modified from DOE, 1991.

MAC: SITE/AMB/LTSP/BASE/POTEN ALLUVIUM

not hydraulically connected to the alluvium/weathered Mancos Shale unit at the Ambrosia Lake site.

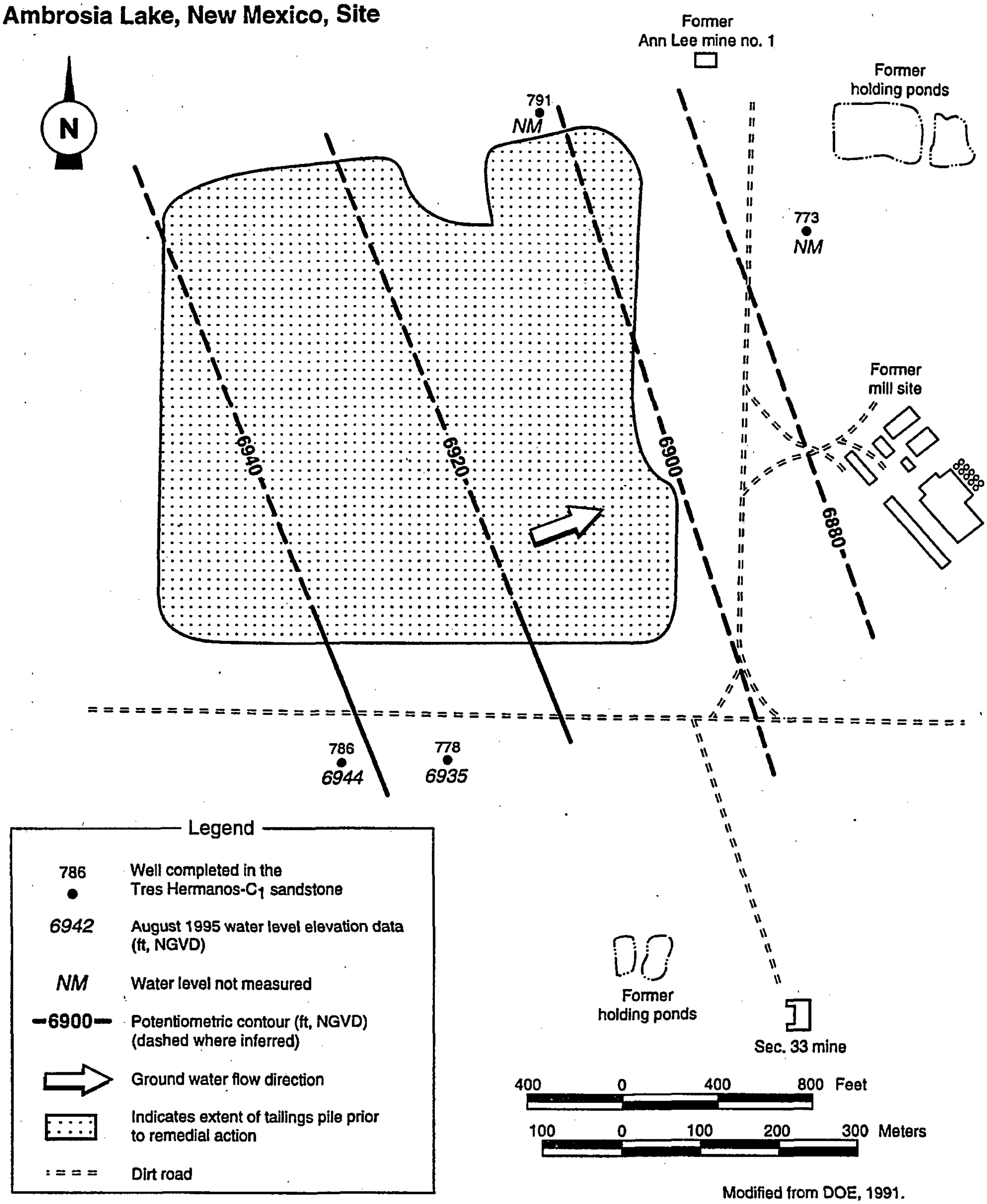
Ground water within both the Tres Hermanos-C_1 and -C_2 Sandstone units flows to the northeast in the direction of regional dip under a hydraulic gradient averaging 0.026 from observations made in 1995 (Figures 5.7 and 5.8). The average hydraulic conductivity in these units is approximately 3×10^{-4} cm per second (0.9 ft per day) and the average linear ground water velocity is approximately 1×10^{-4} cm per second (0.3 ft per day) (DOE, 1991). The Tres Hermanos-C Sandstone units are unconfined in the vicinity of the Ambrosia Lake site, and ground water elevations from monitor wells completed in both the upper and lower sandstone beds suggest that there is basal saturation in each unit. The Tres Hermanos Sandstone may have been saturated in the premining era, but was dewatered by mine construction activities and seepage down mine shafts and vent holes in the vicinity. The basal saturation evident in recent monitor well ground water level measurements is probably sustained by recharge from the alluvium in the subcrop area.

<u>Tres Hermanos-B and -A Sandstones</u>

Underlying the Tres Hermanos-C_2 Sandstone is an unweathered portion of Mancos Shale that acts as an effective aquitard. The shale is approximately 50 ft (15 m) thick and is of sufficiently low-hydraulic conductivity to impede the vertical migration of contaminants. A hydraulic conductivity of 4×10^{-8} cm per second (1.1×10^{-4} ft per day) was estimated in undisturbed Mancos Shale and is probably representative of the vertical hydraulic conductivity of the Mancos Shale aquitard that occurs between the Tres Hermanos-C and the Tres Hermanos-B Sandstones (Thompson and Heggen, 1981). Ground water within the Tres Hermanos-B Sandstone unit flows to the northeast in the direction of regional dip under a hydraulic gradient estimated to be 0.04 (DOE, 1991). Underlying the shale are the Tres Hermanos-B and -A Sandstone units which consist of silty sandstone (Figure 5.3). An aquifer test was performed on the Tres Hermanos-B Sandstone unit yielding an estimated hydraulic conductivity of 5×10^{-4} cm per second (1.4 ft per day). The water-bearing capacity of the Tres Hermanos-B and -A Sandstone units is limited and not much greater than the Mancos Shale.

Based on water levels measured from 1985 to 1995, the Tres Hermanos-B Sandstone unit is only partially saturated. Because the unit is relatively thin and only partially saturated, its use as a potential aquifer is limited. Furthermore, the Tres Hermanos-B Sandstone unit subcrops in the alluvium to the west of the site and contamination in the alluvium from the Ambrosia Lake site probably does not recharge this unit. A 75-ft (23-m) -thick shaley siltstone unit underlies the Tres Hermanos-A Sandstone unit and acts as an effective hydraulic barrier to ground water flow.

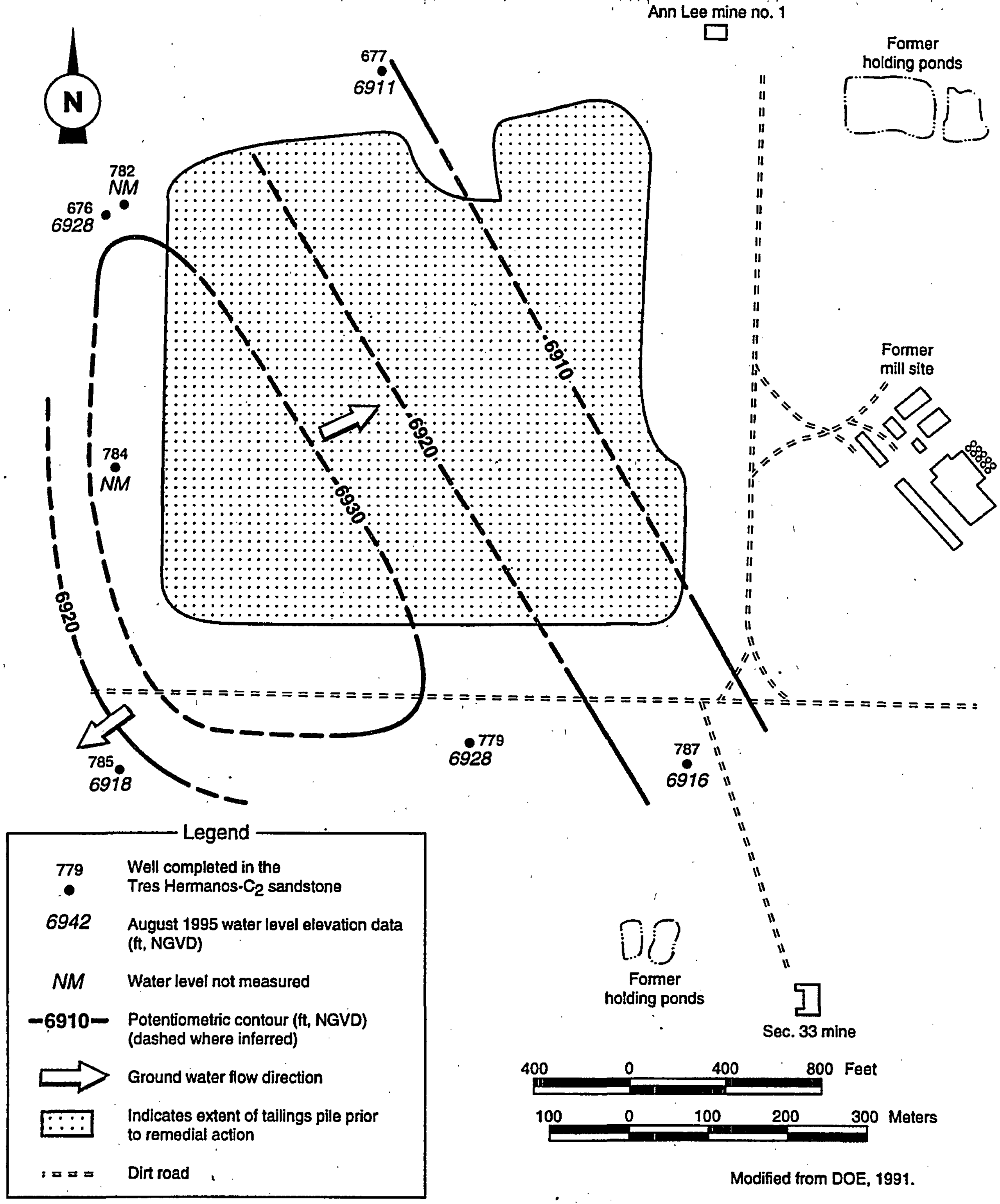
Figure 5.7
Potentiometric Surface Map for Tres Hermanos-C1 Sandstone
Ambrosia Lake, New Mexico, Site



Modified from DOE, 1991.

MAC: SITE/AMB/LTSP/BASE/POTEN HERMANOS-C1

Figure 5.8
Potentiometric Surface Map for Tres Hermanos-C_2 Sandstone
Ambrosia Lake, New Mexico, Site



Modified from DOE, 1991.

MAC: SITE/AMB/LTSP/BASE/POTEN HERMANOS-C2

Dakota Sandstone

The Dakota Sandstone consists of fine to medium grained marine sandstone that is approximately 40 ft (12 m) thick below the Ambrosia Lake site. The hydraulic conductivity of this unit is estimated to be approximately 6 x 10^{-4} cm per second (1.7 ft per day) (Brod and Stone, 1981). The Dakota Sandstone is considered an aquifer although it has a relatively low yield (less than 10 gal [40 L] per minute) and poor water quality, when compared to the underlying Westwater Canyon Member of the Morrison Formation (DOE, 1987). Bostick (1985) reports that the Dakota Sandstone is present at the land surface near the QMC mill approximately 2 mi (3 km) west of the site and that surface water related to the QMC processing activities was discharged onto the outcrop of the Dakota Sandstone which has caused the contamination of the unit. The discharge of contaminated water at the outcrop area and the discharge of water from mill tailings placed in surrounding mines are the primary sources of contaminants found in the Dakota Sandstone beneath the Ambrosia Lake site.

Morrison Formation

The stratigraphic units that comprise the Morrison Formation beneath the site include the Brushy Basin Member, Westwater Canyon Member, and the Recapture Member. The Brushy Basin Member acts as an aquitard between the Dakota Sandstone and Westwater Canyon Member.

The Westwater Canyon Member is the principal aquifer in the Ambrosia Lake Mining District and is also the source of uranium ore. Mine pumping began in the mid-1950's to facilitate ore removal from the Westwater Canyon Member. Because of the regional mine pumping, a large ground water depression was created. Ground water flow within the Westwater Canyon Member is probably downdip toward the northeast or toward the potentiometric depression to the southeast under an assumed average hydraulic gradient of 0.026 (DOE, 1991). The average hydraulic conductivity in the Westwater Canyon Member is approximately 4 x 10^{-4} cm per second (1.1 ft per day) and the average linear ground water velocity is approximately 1 x 10^{-4} cm per second (0.3 ft per day) (DOE, 1991). The Recapture Member acts as an aquitard beneath the Westwater Canyon Member because of its thickness (165 ft [50 m]) and low permeability.

5.1.4 Background ground water quality

Because there was originally no measurable water in the alluvium/weathered Mancos Shale unit and the Tres Hermanos-C Sandstone units, premining ground water quality data are not available. Consequently, the background ground water quality in the uppermost aquifer is considered to be the same as existing water quality because former mining and milling activities created the saturated conditions (Bostick, 1985). Geochemical modeling shows that the ground water within the alluvium/weathered Mancos Shale is derived from tailings seepage and mill makeup water (DOE, 1991). The mill makeup water was generated from mine pumping discharge. Modeling results are presented in the remedial action plan (Table D.8.25 of DOE, 1991).

5.1.5 Ground water quality and extent of contamination

To define the extent of contaminated ground water at the Ambrosia Lake site, water samples were collected from a DOE monitor well network from 1980 through 1995. Figure 5.2 shows a portion of the DOE monitor well network used to determine current site conditions. Water samples collected from this monitor well network have been analyzed to assess the chemical quality of ground water in the alluvium/weathered Mancos Shale, the Tres Hermanos-C, -B, and -A Sandstones, and the Westwater Canyon Member of the Morrison Formation.

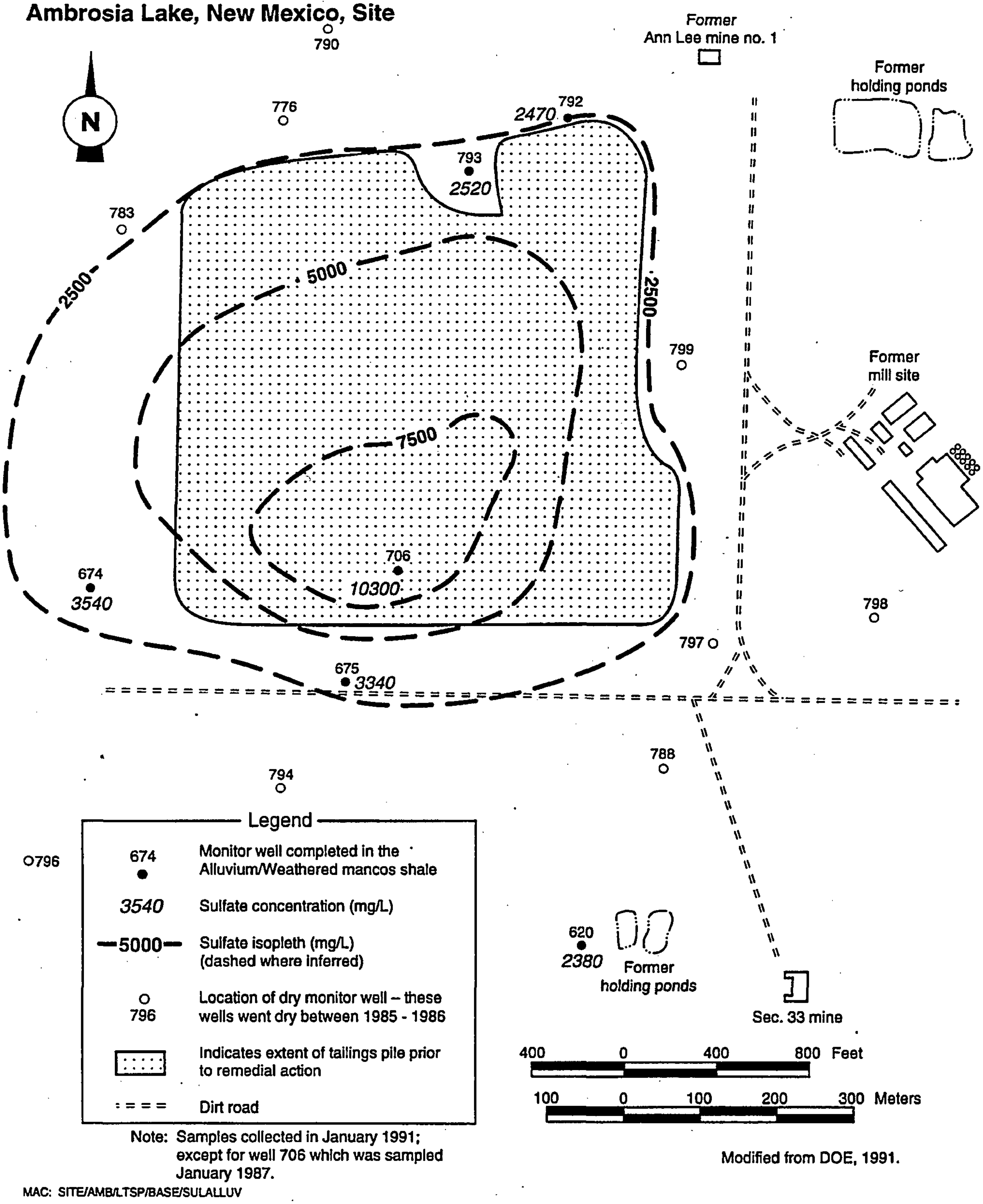
The majority of the contaminated ground water contained in the alluvium/weathered Mancos Shale unit and Tres Hermanos-C Sandstone units in the area of the milling site was derived from water pumped from the Ann Lee Mine, mill process waste water, and some tailings seepage. Because of the large ground water depression created by mine pumping, ground water from all overlying units will tend to migrate downward through mine shafts and vent holes into the Westwater Canyon Member of the Morrison Formation.

Alluvium/weathered Mancos Shale

Pore water from tailings at the Ambrosia Lake site contained as much as 11,000 mg/L sulfate (DOE, 1991). Sulfate is a good indicator of ground water contamination because it is a by-product of milling operations, travels at about the same rate as ground water, and is usually in low concentrations in uncontaminated ground water. A sulfate isopleth map (Figure 5.9) is used to define the extent of tailings-related contamination and, very likely, the extent of ground water in the alluvium/weathered Mancos Shale at the site. Monitor well 620 is located more than 1200 ft (370 m) southeast of the ground water mound. The contaminated ground water in this well, as indicated by significantly high sulfate concentrations, is assumed to be derived from the former holding ponds located to the east and from transient drainage from the tailings pile that occurred prior to site remedial action. From 1980 through 1994, maximum observed concentrations of arsenic, cadmium, chromium, molybdenum, nitrate, selenium, silver, uranium, and the activities of gross alpha, radium-226, and radium-228 in samples collected from monitor wells completed in the alluvium/weathered Mancos Shale exceeded the maximum concentration limits (MCL) for ground water listed in 40 CFR Part 192, as revised by 60 FR 2854 (Table 5.2) (DOE, 1995).

The Tres Hermanos-C_1 Sandstone is separated from the underlying Tres Hermanos-C_2 Sandstone by a 10- to 15-ft (3- to 5-m) -thick shale unit. This shale unit retards downward migration of contaminants, resulting in slightly higher levels of contamination in the Tres Hermanos-C_1 Sandstone (Table 5.3), compared to values in the Tres Hermanos-C_2 Sandstone (Table 5.4). There are

Figure 5.9
Sulfate Isopleth Map For Ground Water in the Alluvium/Weathered Mancos Shale Ambrosia Lake, New Mexico, Site



Note: Samples collected in January 1991; except for well 706 which was sampled January 1987.

Modified from DOE, 1991.

MAC: SITE/AMB/LTSP/BASE/SULALLUV

Table 5.2 Maximum observed concentrations of listed constituents in monitor wells located in the alluvium/weathered Mancos Shale at the Ambrosia Lake, New Mexico, site, 1980 to 1994

Constituent[a]	MCL[b]	Maximum observed concentration[a] — Monitor wells: 620	674	675	706	792	793
	(mg/L)						
Arsenic	0.05	0.01	0.02	0.02	0.33[c]	0.016	0.016
Barium	1	0.1	<0.1	0.01	<0.1	<0.1	<0.1
Cadmium	0.01	<0.001	0.003	0.003	<0.001	0.01	0.013[c]
Chromium	0.05	0.16[c]	<0.01	<0.01	0.06[c]	0.28[c]	0.28[c]
Lead	0.05	0.02	0.03	0.02	0.02	0.02	0.02
Mercury	0.002	<0.0002	<0.0002	<0.0002	<0.002	0.0007	0.0003
Molybdenum	0.1	0.5[c]	9.81[c]	2.72[c]	225[c]	1.87[c]	2.01[c]
Nitrate	44[d]	12.1	69[c]	252[c]	25	1.8	830[c]
Selenium	0.01	0.07[c]	3.1[c]	0.51[c]	0.088[c]	2.22[c]	2.1[c]
Silver	0.05	0.04	0.01	0.02	0.15[c]	0.11[c]	0.11[c]
Combined Uranium-234 and -238	0.044[e]	8.22[c]	10.7[c]	2.083[c]	11.1[c]	3.31[c]	0.393[c]
	pCi/L						
Gross alpha (excluding radon and uranium)	15	5300[c]	2200[c]	1700[c]	15,000[c]	2400[c]	320[c]
Combined Radium-226 and -228	5	9.13[c]	0.8	4.03	131.8[c]	6.85[c]	2.3

[a]All concentrations are in mg/L unless stated otherwise.
[b]Constituents and maximum concentration limits (MCL) from Table 1 of 40 CFR Part 192, as revised by 60 FR 2854.
[c]Exceeds MCL.
[d]The MCL for nitrate as (N) is 10 mg/L.
[e]The uranium concentration of 0.044 mg/L is equivalent to 30 pCi/L, which is the MCL.

Table 5.3 Maximum observed concentrations of listed constituents in monitor wells located in the Tres Hermanos-C_1 Sandstone at the Ambrosia Lake, New Mexico, site, 1980 to 1994

Constituent[b]	MCL[b]	Maximum observed concentration[a] Monitor wells 778	786
	(mg/L)		
Arsenic	0.05	0.022	0.02
Barium	1	<0.1	0.3
Cadmium	0.01	0.014[c]	0.013[c]
Chromium	0.05	0.22[c]	0.14[c]
Lead	0.05	0.02	0.02
Mercury	0.002	0.0005	0.0003
Molybdenum	0.1	0.16[c]	0.34[c]
Nitrate	44[d]	430[c]	55[c]
Selenium	0.01	0.28[c]	0.78[c]
Silver	0.05	0.06[c]	0.02
Combined Uranium-234 and -238	0.044[e]	11.8[c]	2.88[c]
	pCi/L		
Gross alpha (excluding radon and uranium)	15	9400[c]	1300[c]
Combined Radium-226 and -228	5	7.93[c]	9.92[c]

[a]All concentrations are in mg/L unless stated otherwise.
[b]Constituents and maximum concentration limits (MCL) from Table 1 of 40 CFR Part 192, as revised by 60 FR 2954.
[c]Exceeds MCL.
[d]The MCL for nitrate as (N) is 10 mg/L.
[e]The uranium concentration of 0.044 mg/L is equivalent to 30 pCi/L, which is the MCL.

Table 5.4 Maximum observed concentrations of listed constituents in monitor wells located in the Tres Hermanos-C_2 Sandstone at the Ambrosia Lake, New Mexico, site, 1980 to 1994

		Maximum observed concentration[a]				
		Monitor wells				
	MCL[b]	779	785	787	677	676
Constituent[b]	(mg/L)					
Arsenic	0.05	0.025	0.012	0.019	<0.01	<0.01
Barium	1	0.3	0.1	0.01	0.01	0.01
Cadmium	0.01	0.016[c]	0.024[c]	0.012[c]	0.004	0.003
Chromium	0.05	0.22[c]	0.24[c]	0.23[c]	<0.01	<0.01
Lead	0.05	0.02	0.02	0.02	0.05	0.04
Mercury	0.002	0.0006	0.0006	0.0004	<0.0002	<0.0002
Molybdenum	0.1	0.14[c]	0.35[c]	0.25[c]	0.024	0.595[c]
Nitrate	44[d]	2.29	20	29	6.9	25.6
Selenium	0.01	0.092[c]	0.324[c]	0.054[c]	0.037[c]	0.091[c]
Silver	0.05	0.05	0.08[c]	0.09[c]	<0.01	<0.01
Combined Uranium-234 and -238	0.044[e]	0.0238	3.30[c]	0.018	0.016	0.207[c]
	pCi/L					
Gross alpha (excluding radon and uranium)	15	74[c]	1900[c]	57.4[c]	29[c]	85.9[c]
Combined Radium-226 and -228	5	5.6[c]	10.51[c]	4.2	6.45[c]	24.12[c]

[a]All concentrations are in mg/L unless stated otherwise.
[b]Constituents and maximum concentration limits (MCL) from Table 1 of 40 CFR Part 192, as revised by 60 FR 2854.
[c]Exceeds MCL.
[d]The MCL for nitrate as (N) is 10 mg/L.
[e]The uranium concentration of 0.044 mg/L is equivalent to 30 pCi/L, which is the MCL.

insufficient data to compile a sulfate isopleth map for the Tres Hermanos-C_1 Sandstone. A sulfate isopleth map (Figure 5.10) shows the approximate extent of tailings-related contamination in the Tres Hermanos-C_2 Sandstone. This map indicates that contamination has moved farther downgradient to the northeast as compared to Figure D.8.24 in the remedial action plan (DOE, 1991). From 1980 through 1994, maximum observed concentrations of cadmium, chromium, molybdenum, nitrate, selenium, silver, uranium, and the activities of gross alpha, radium-226, and radium-228 in samples collected from monitor wells completed in the Tres Hermanos-C_2 Sandstone exceeded the MCLs for ground water (Table 5.4). Maximum concentrations of several parameters in the Tres Hermanos-C sandstone units have increased over those of previous years indicating that contamination is moving downgradient (DOE, 1995).

Units below the Tres Hermanos-C Sandstone

Water bearing units below the Tres Hermanos-C Sandstone include, in descending order, the Tres Hermanos-B and -A Sandstones, the Dakota Sandstone, and the Westwater Canyon Member of the Morrison Formation. Ground water from monitor wells completed in these units does not appear to be affected by site-related contamination.

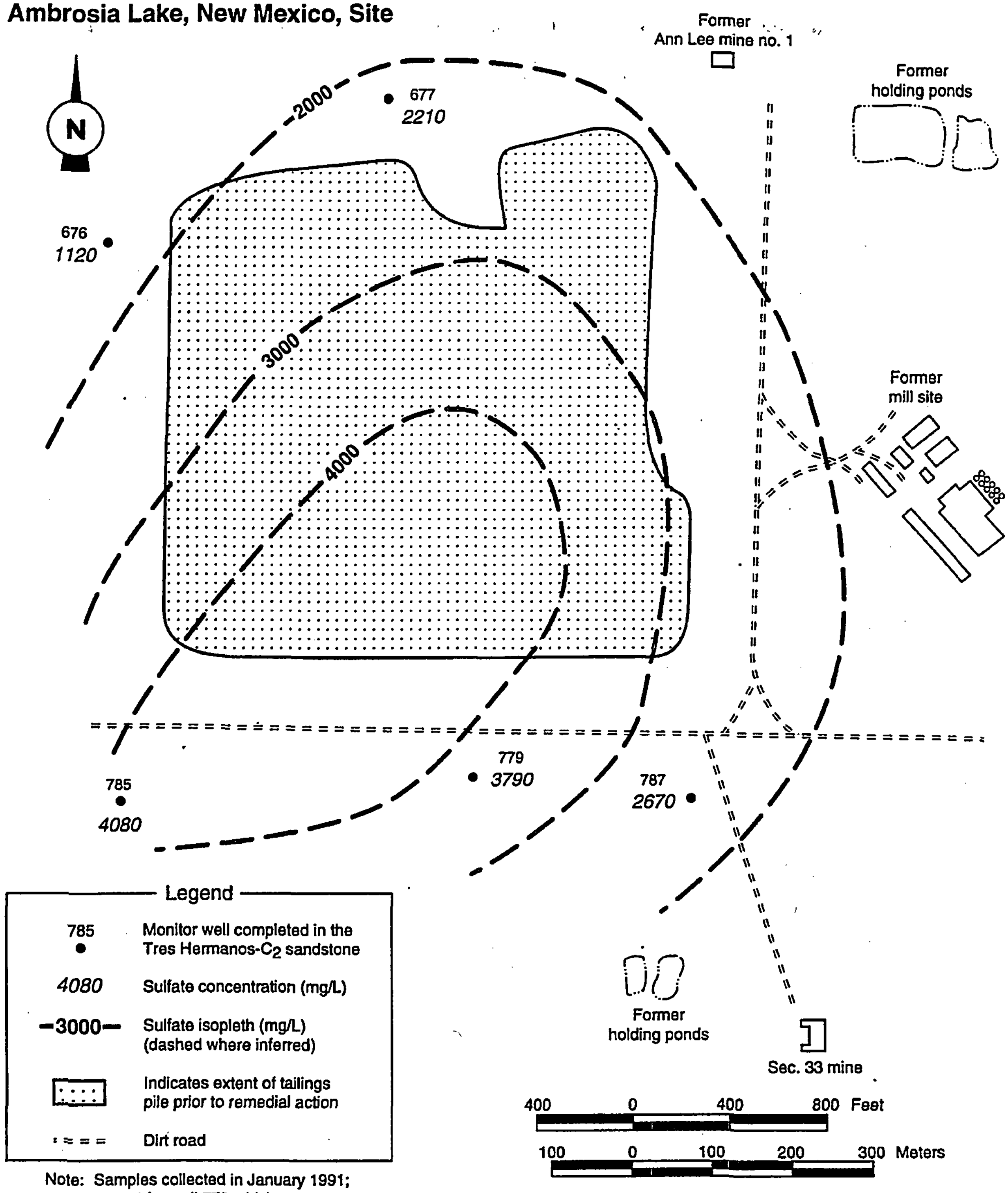
From 1989 to 1994, nitrate levels increased in monitor well 678, which is completed in the Tres Hermanos-B Sandstone (DOE, 1995). This increase is probably not related to uranium processing at the Ambrosia Lake site because it is not accompanied by increases in other relatively mobile site-related parameters (e.g. molybdenum, sulfate, or uranium), and nitrate concentrations in monitor well 678 (approximately 3400 mg/L) are much higher than average concentrations found in tailings pore fluids (approximately 1400 mg/L). Furthermore, the Tres Hermanos-B Sandstone is hydrologically isolated from the alluvium/weathered Mancos Shale unit at the site (see Section 5.1.3). The relatively high nitrate levels are most likely related to releases from the QMC tailings pile (DOE, 1995).

The Westwater Canyon Member is the primary source of uranium ore in the area and was the focus of intense mining-related activity. Thus, mining activities not related to UMTRA Project site tailings seepage introduced many other sources of contamination into the Westwater Canyon Member. The DOE made a comparison of concentrations of contaminants in the Tres Hermanos-C Sandstone with the Westwater Canyon member (Table D.8.26 of DOE, 1991) and concluded that, in general, concentrations of site contaminants in the Tres Hermanos-C Sandstone are lower. This suggests that seepage from the Tres Hermanos-C Sandstone ground water will produce no increases in the concentrations of contaminants in the Westwater Canyon Member.

5.2 GROUND WATER MONITORING PLAN

No ground water monitoring is required for the long-term surveillance program at the Ambrosia Lake disposal site for compliance with ground water protection

Figure 5.10
Sulfate Isopleth Map for Ground Water in the Tres Hermanos-C_2 Sandstone Ambrosia Lake, New Mexico, Site



Note: Samples collected in January 1991; except for well 779 which was sampled September 1989.

Modified from DOE, 1991.

MAC: SITE/AMB/LTSP/BASE/SULFATEISOTRESHERMANOS-C2 standards at 40 CFR Part 192, Subparts A and C, as revised by 60 FR 2854, or for demonstration of disposal cell performance. The DOE has adequately justified that the proposed supplemental standards are protective of human health and the environment and has demonstrated that the remedial action comes as close to meeting the otherwise applicable standards as is reasonable under the circumstances. Consequently, the NRC has concurred in the application of supplemental standards at the Ambrosia Lake disposal site and the exemption of both the compliance and performance elements of ground water monitoring requirements (NRC, 1990).

The DOE conducted the last scheduled sampling event for the Ambrosia Lake site in August 1995. This event completed the water sampling requirements for the surface remedial action program. The need for additional characterization or ground water sampling is not expected for compliance with 40 CFR Part 192 Subpart B, as revised by 60 FR 2854. The rationale for not monitoring ground water further is discussed in Appendix E of the Ambrosia Lake remedial action plan (DOE, 1991). Attachment 1 contains a copy of the transmittal letter for the NRC's technical evaluation report (NRC, 1990) concurring with the remedial action plan and the ground water protection strategy.

If subsequent evaluations conducted as part of the DOE UMTRA Ground Water Project identify a need to continue ground water monitoring at the Ambrosia Lake disposal site, the scope of the monitoring program will be addressed in a future revision of the LTSP.

6.0 SITE INSPECTIONS

Routine inspections of the Ambrosia Lake disposal site will be conducted to detect progressive change caused by slow-acting natural processes and to identify potential problems before the need for extensive maintenance, repairs, or corrective action. The findings from these inspections will be compared to initial baseline conditions to provide a basis for future inspections.

Each site inspection must be thoroughly documented. An inspection report will be prepared that identifies the findings of the inspection and that records any changes to the disposal cell and site over time. Copies of the report will be submitted to the NRC and will be placed in the Ambrosia Lake DOE permanent site file (Section 10.0).

The three types of site inspections are as follows:

- Routine annual or scheduled site inspections.
- Follow-up inspections.
- Contingency inspections.

The requirements discussed in this section apply to the conduct of routine annual or scheduled site inspections. Additional requirements for follow-up or contingency inspections are discussed in Section 7.0.

6.1 INSPECTION FREQUENCY

The Ambrosia Lake disposal site will be inspected annually for the first 5 years after licensing. At the end of the 5-year period, the GJPO will evaluate the need to continue annual inspections, basing its recommendation on an evaluation of the annual reports and any other reports filed for maintenance or unscheduled events. If it is determined that less frequent inspections are required, the GJPO will modify the LTSP and submit it to the NRC for acceptance. Subsequent routine inspections will be considered scheduled site inspections.

6.2 INSPECTION TEAM

The inspection team will consist of a chief inspector and one or more assistants. The chief inspector will be a geotechnical engineer, a civil engineer, or an engineering geologist knowledgeable in processes that could adversely affect the site (e.g., geomorphic agents of change). A plant specialist or other qualified person will periodically participate in site inspections. If the annual or scheduled inspection does not coincide with the general growing season, the plant specialist may conduct a separate inspection at a more favorable time.

When they are needed for follow-up or contingency inspections, the team will include additional technical experts to assess the problems under investigation.

For example, a follow-up inspection by a plant specialist may be required if an inspection team reports significant plant growth on the rock cover.

6.3 PREPARATION FOR INSPECTION

Before each inspection, inspectors will complete the following tasks:

- Review the final LTSP, the permanent site file, the previous site inspection report(s) and site inspection map(s), and all maintenance or corrective action reports.
- Prepare the site inspection checklist based on previous inspections or repairs; incorporate any needed modifications.
- Verify and update the names and telephone numbers of all parties with whom access or notification agreements have been executed.
- Verify the DOE 24-hour telephone number and appropriate agency telephone numbers and contacts; arrange to modify the entrance sign, as needed.
- Schedule the site inspection.
- Assemble all equipment needed for the inspection.
- Adjust the magnetic declination of the Brunton compass for that of the Ambrosia Lake area.
- Notify the NRC, QMC, and, if appropriate, the state of New Mexico and adjacent land owners of the schedule for the forthcoming inspection. Names and addresses of adjacent land owners are in the Ambrosia Lake permanent site file.
- Obtain key to gate lock if QMC installs a gate on the access road (see Section 2.3).

6.4 ROUTINE SITE INSPECTION

The routine site inspection will cover the disposal cell, the surrounding disposal site area, and the immediate off-site areas. The most significant modifications from natural processes likely will be on the slopes of the disposal cell and in and around the apron. Plant, animal, and human intrusion can also cause modifications to the engineered components of the disposal cell. Site inspections must be able to identify any significant changes or active modifying processes that could potentially adversely impact the disposal cell or the debris pit. Surveillance should be performed to identify unanticipated effects of modifying processes such as severe gully formation, unusually high rate of slope erosion, significant changes to vegetation, ephemeral drainage channel changes, and significant modifications by humans or animals.

6.4.1 On-site areas

The integrity of the disposal cell will be evaluated from a series of transects walked around the perimeter; along the base, crest, and sideslopes; and in and around the apron. Sufficient transects must be walked so that the disposal cell is thoroughly covered and inspected. Diagonal transects of the crest will be made, and the edge of the crest will be walked. Additional transects, at approximately 50-yard (50-m) intervals, will be walked along the sideslopes and rock apron. Transects along the entire length of the drainage swales will be made to determine whether they have been functioning as designed and can be expected to continue to function properly.

The complete length of transects along the engineered disposal cell and its immediate perimeter will be examined for evidence of the following:

- Structural instability resulting from differential settlement, subsidence, cracking, sliding, or creep.
- Erosion as evidenced by developing rills or gullies.
- Sedimentation or debris buildup.
- Rapid rock cover deterioration caused by weathering or erosion.
- Seepage from the disposal cell.
- Intrusive activity (inadvertent or deliberate) by humans such as removal of rock or other disposal cell material or vandalism.
- Burrowing or other significant disturbance by animals.
- Volunteer plant growth on the rock-covered slopes of the disposal cell.

At minimum, the surrounding disposal site area will be monitored for evidence of erosion caused by wind, sheet wash, or changes in drainage patterns. Site inspections also will monitor damage to or disturbance of the following features:

- Permanent site-surveillance features.
- Ground water monitor wells.
- Drainage swales.
- Planned site area vegetation (see below).
- Vent shafts.
- Demolition debris pit.

The disposal cell has a rock cover and there is no planned vegetation on the disposal cell. However, remedial action of the areas surrounding the disposal cell included revegetation with grasses and forbs (Table 6.1). The area surrounding the disposal cell will be monitored during site inspections to determine the success of the revegetation efforts.

6.4.2 Off-site areas

The area within a maximum of 0.25 mi (0.40 km) from the disposal site boundary will be visually surveyed from the disposal site for evidence of land-use changes that indicate increased human activity such as renewed grazing or mining. New roads or paths, changes in vegetation, and relevant geomorphic features like gullies or ephemeral drainage channels will also be observed and potential impact noted. Inspectors should avoid trespassing on private property surrounding the site. If there is a need for closer inspection of off-site features, inspectors shall obtain permission in advance from the property owner.

A restrictive easement on QMC property west of the disposal site (Tract 2B-E) allows the DOE access to carry out the requirements of this LTSP (see Figure 1.1 and Attachment 2). Conventional mining is restricted within 400 ft (120 m) of the westerly edge of the disposal cell; however, QMC retains mineral rights in this area and any resumption of solution mining should be noted. QMC is required to maintain the woven wire and barbed wire fencing to the south and west of the disposal site and the cattle guard across the access road at the site entrance for 5 years (Charlton, 1995). The fencing and cattle guard will be inspected to determine if this maintenance requirement is being met. The vent shaft outside the west side of the site will be monitored during site inspections to determine if the property owner permanently closes it. If the shaft is closed, information on the closure method should be obtained for the site file.

Off-site DOE monitor wells shall be inspected until they are properly abandoned.

6.5 SITE INSPECTION DOCUMENTATION

All site inspection activities and observations should be recorded and described using the site inspection checklist, site inspection map, a field notebook, photographs, and logs. Documentary evidence of anomalous, new, or unexpected conditions or situations must be sufficient to record developing trends and to enable the responsible agency to make reasonable decisions concerning follow-up inspections, custodial maintenance, and corrective action. A site inspection report will be prepared documenting the findings and recommendations from each field inspection.

6.5.1 Site inspection checklist

The initial site inspection checklist (Attachment 4) is a guideline for the inspectors to prepare for and conduct site inspections. All checklist items should be completed. Annotations should be made on the checklist to add more

Table 6.1 Revegetation seeding mixes, Ambrosia Lake, New Mexico, site

Location and seed species	Seeding rate Live seed pounds per acre (kg/ha)
<u>Drainage swales and ditches</u>	
slender wheatgrass (San Luis)	6 (1)
western wheatgrass (Arriba)	6 (1)
<u>Final grade, except drainage swales and ditches</u>	
western wheatgrass (Arriba)	6 (1)
Indian ricegrass (Paloma)	6 (1)
alkali sacaton (native)	2 (0.4)
sand dropseed	2 (0.4)
four-wing saltbush (native)	2 (0.4)
Rocky Mountain penstemon (Bandera)	1 (0.2)

kg/ha – kilograms per hectare.

detailed information and all entries must be clearly stated and legible because the completed checklist becomes part of the permanent field record of the inspection. Upon completion of the field inspection, Section D of the site inspection checklist (Attachment 4) must be completed and the certification statement must be signed.

After each inspection is complete, the checklist may be revised, if necessary, to include new information or to delete items that are no longer pertinent. Revisions to the checklist will be documented in the inspection report.

6.5.2 <u>Site inspection maps</u>

The disposal site baseline map (Plate 1) will serve as the base for preparing the site inspection map. The inspection team will use copies of the site inspection map during site inspections and annotate these field maps as necessary to record pertinent information.

A new site inspection map will be prepared after each scheduled inspection for inclusion in the inspection report. The site inspection map must include the following information:

- Inspection traverses.
- Photographic locations.
- Locations and descriptions of any new, anomalous, or unexpected features.

- Features identified during previous inspections for observation or monitoring.
- Inspection date and type of inspection.

Upon completion of the field inspection, the annotated inspection map may be used to prepare overlays for the as-built drawings or revise the drawings to note any potential problems or other site conditions requiring attention.

6.5.3 Site inspection photographs

A photographic record of the site inspection must be maintained. Site conditions should be documented by ground photographs to record developing trends and to enable the DOE to evaluate the need for and extent of future activities. If possible, any site feature or condition requiring inspectors to make a written comment, explanation, or description will be photographed. A site inspection photo log will be used to record the photographs (Attachment 3). A separate photo log should be completed for each roll of exposed film, with an entry for each photograph. All features will be photographed and recorded as specified below. The inspectors may determine the number of photographs, the view angles, and the lenses used to ensure that sufficient photographs are taken for agency review.

If possible, a photograph will include a reference point such as a survey monument, boundary monument, site marker, or monitor well. For large-scale features such as drainage swales or disposal cell slopes, a north arrow and a scale will be included for reference. For specific areas where a photograph is used to monitor change over time, the distance from the feature and the azimuth should be recorded, and all subsequent photographs should be taken from the same orientation to provide an accurate picture of changing conditions. The magnetic declination of the compass should be corrected for true north. This information will also be provided on the inspection checklist and photo log.

Features to be photographed

The following site features should be documented with photographs during scheduled inspections at the Ambrosia Lake disposal site:

- Permanent site-surveillance features (Section 4.0) and survey control point for site grid coordinate system.

- Access road.

- Drainage swales and debris pit area.

- The disposal cell (top, sides, apron, and surrounding area). Panoramic sequences of photographs from selected vantage points may be used for this purpose.

- Vent shafts.
- Any evidence of erosion (e.g., gullies, rivulets, and rills) that the inspector considers significant and includes in the text of the inspection report.
- Any off-site features that may affect the site in the future and that the inspector considers significant and includes in the inspection report.
- Vegetation (site area and disposal cell slopes).
- Monitor wells (until abandoned).

Any new or potential problem areas identified during a site inspection must be well documented with photographs. Photographs should also be taken to record developing trends and to allow inspectors to make reasonable decisions concerning additional inspections, custodial maintenance or repairs, or corrective action. All site inspection photographs, as well as all corresponding photo log forms, will be maintained in the permanent site file.

6.5.4 Site inspection report

The GJPO will prepare a site inspection report after every routine site inspection that discusses scope of the inspection, observations made, and conclusions drawn from the inspection. At a minimum the inspection report will include:

- Narrative of site inspection including a description of the site conditions.
- Site inspection checklists, including the signed inspection certification, and any relevant supporting documentation.
- Site inspection map and other drawings, maps, or figures, as required.
- Inspection photographs and photo log sheets.
- Recommendations for additional follow-up inspections, custodial maintenance, or repairs, if required.
- Custodial maintenance or repair report and certification, if any was performed.

If new conditions requiring monitoring or immediate action are discovered during the inspection, the inspection report will detail any observed modifying features, and will include a description of the problem, relevant measurements and photographs, and an assessment of possible impacts. The description of the modifying process will include information such as the following:

- Extent of area affected.

- Number, spacing, length, depth, and width of features (e.g., gullies).
- Locations and patterns of occurrence.
- Species, location and density of volunteer plant growth.

Evidence of deliberate and repeated human intrusion such as cover removal, extensive vandalism to signs and monuments, or the presence of well-established trails will be described in detail. While inadvertent or casual intrusion by humans is not of great concern, all signs of vandalism will be noted since evidence of continued vandalism may indicated the need to implement more active measures to control site access.

All site inspection reports, as well as all supporting documentation, will be maintained in the permanent site file.

REFERENCES

5-8

Ambrosia Lake, New Mexico, Disposal Site

FACT SHEET

This fact sheet provides information about the Uranium Mill Tailings Radiation Control Act of 1978 Title I disposal site located at Ambrosia Lake, New Mexico. The site is managed by the U.S. Department of Energy Office of Legacy Management.

Site Description and History

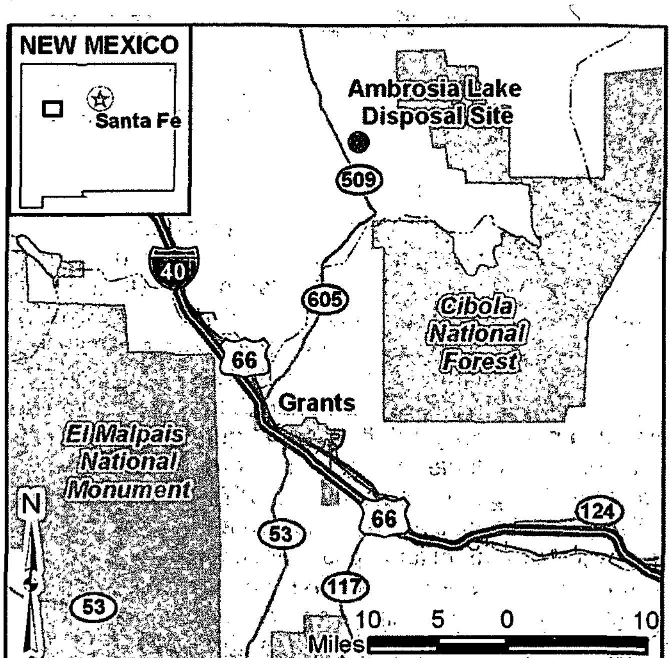
The Ambrosia Lake Disposal Site is a former uranium ore processing facility in McKinley County, approximately 25 miles north of Grants, New Mexico. The site is in the Ambrosia Lake Valley, a broad, elongate valley dominated by desert grassland plant communities and basalt-capped mesas to the north. The site is within the Ambrosia Lake Mining District, near the center of the Grants Mineral Belt. Decommissioned uranium mills, abandoned underground mines, mine shafts and vents, ore piles, tailings piles, and heap leach piles are close to the site. The area surrounding the millsite is sparsely populated.

The former mill processed more than 3 million tons of uranium ore between 1958 and 1963 and provided uranium for U.S. Government national defense programs. Phillips Petroleum Company built the original mill at the Ambrosia Lake site in 1957 to process ore from nearby mines. United Nuclear Corporation purchased and operated the mill for a brief period in 1963, then ceased milling operations but retained ownership of the site. In the late 1970s to early 1980s, United Nuclear Corporation operated an ion exchange system, extracting uranium from mine water. All mill operations ceased in 1982, leaving radioactive mill tailings, a predominantly sandy material, on approximately 111 acres. Wind and water erosion spread some of the tailings across a 230-acre area.

The U.S. Department of Energy (DOE) remediated the Ambrosia Lake site and local contaminated vicinity properties between 1987 and 1995. Surface remediation consisted of consolidating and encapsulating all contaminated material on site in an engineered disposal cell. The disposal cell occupies 91 acres of a 290-acre tract of land.

Regulatory Setting

Congress passed the Uranium Mill Tailings Radiation Control Act (UMTRCA) in 1978 (Public Law 95-604), which required the cleanup of 24 inactive uranium ore-processing sites. DOE remediated these sites under the Uranium Mill Tailings Remedial Action Project in accordance with standards promulgated by the U.S. Environmental Protection Agency in Title 40 *Code of Federal Regulations* (CFR) Part 192. Subpart B of



M:\LTS\111\0001\04\001\S01822\S0182200.mxd carverh 9/19/2007 12:34:01 PM

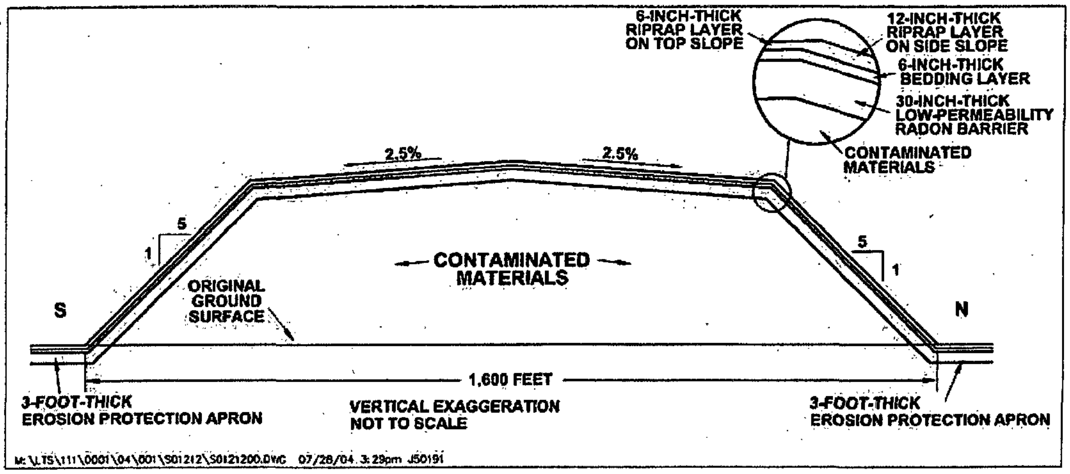
Location of the Ambrosia Lake Disposal Site

40 CFR 192 regulated cleanup of contaminated ground water at the processing sites. The radioactive materials were encapsulated in U.S. Nuclear Regulatory Commission-approved disposal cells. The U.S. Nuclear Regulatory Commission general license for UMTRCA Title I sites is established in 10 CFR 40.27. The Ambrosia Lake Disposal Site was included under the general license in 1998.

Disposal Site

The disposal cell was closed in 1995 upon encapsulation of the tailings and completion of the cell cover. The cell contains 6.9 million dry tons (about 5.2 million cubic yards) of contaminated material, with a total activity of 1,850 curies of radium-226.

The uppermost aquifer beneath the site consists of alluvium (river deposits), sandstone, and weathered shale. The maximum thickness of the aquifer is approximately 175 feet; the maximum saturated thickness is 25 feet. This uppermost aquifer is not a current or potential source of drinking water because of low yield.



South-North Cross Section of the Ambrosia Lake Disposal Site

Compliance Strategy

The ground water compliance strategy for the Ambrosia Lake Disposal Site is no remediation and the application of supplemental standards. The strategy of supplemental standards may be applied at UMTRCA sites where ground water in the uppermost aquifer is classified as limited use because it meets any of several criteria. Ground water at the Ambrosia Lake site meets the criterion of low yield, that is, the quantity of water reasonably available for sustained continuous use is less than 150 gallons per day (40 CFR 192.11[e]). Past milling operations, such as wastewater disposal and seepage from the tailings pile, supplied most of the water that recharged the aquifer. Those sources no longer exist, and the tailings and other contaminated materials are encapsulated in an engineered disposal cell. The alluvium is expected to return to the conditions of little to no saturation that prevailed before milling and mining began in the area. Because ground water is not a present or potential resource, no monitoring is required at the site. However, at the request of the New Mexico Environment Department, DOE samples two monitor wells every 3 years to monitor cell performance.

Disposal Cell Design

The rectangular disposal cell measures approximately 2,500 feet by 1,600 feet, including the toe apron. The cell rises approximately 50 feet above the surrounding terrain.

The cover of the Ambrosia Lake disposal cell is a multicomponent system designed to encapsulate and protect the contaminated materials. The disposal cell cover comprises (1) a low-permeability radon barrier (first layer placed over compacted tailings) consisting of compacted clayey soil, (2) a bedding layer of granular bedding material, and (3) a rock (riprap) erosion-protection layer for the top and side slopes.

A rock apron of larger diameter riprap surrounds the toe of the disposal cell. The ground immediately adjacent to the cell perimeter has been graded away from the cell to protect the site from storm water runoff. Disturbed areas have been successfully revegetated.

Legacy Management Activities

DOE manages the disposal site according to a site-specific Long-Term Surveillance Plan to ensure that the disposal cell systems continue to prevent release of contaminants to the environment. Under provisions of this plan, DOE conducts annual inspections of the site to evaluate the condition of surface features, performs site maintenance as necessary, and samples two monitor wells every 3 years. The encapsulated materials will remain potentially hazardous for thousands of years.

In accordance with 40 CFR 192.32, the disposal cell is designed to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. However, the general license has no expiration date, and DOE's responsibility for the safety and integrity of the Ambrosia Lake Disposal Site will last indefinitely.

Contacts

Site-specific documents related to the Ambrosia Lake Disposal Site are available on the DOE Office of Legacy Management website at http://www.LM.doe.gov/land/sites/nm/amb/amb.htm.

For more information about the DOE Office of Legacy Management activities at the Ambrosia Lake Disposal Site, contact

U.S. Department of Energy
Office of Legacy Management
2597 B¾ Road, Grand Junction, CO 81503

(970) 248-6070 (monitored continuously), or
(877) 695-5322 (toll-free)

UMT 16943

16.13.1.6

DOE/EA - 0322

SURF022847

Environmental Assessment

Remedial Action at the Ambrosia Lake Uranium Mill Tailings Site Ambrosia Lake, New Mexico

June, 1987

DOE/EA-0322

ENVIRONMENTAL ASSESSMENT

OF

REMEDIAL ACTION AT THE AMBROSIA LAKE

URANIUM MILL TAILINGS SITE

AMBROSIA LAKE, NEW MEXICO

TEXT

JUNE, 1987

U.S. DEPARTMENT OF ENERGY

UMTRA PROJECT OFFICE

ALBUQUERQUE, NEW MEXICO

TABLE OF CONTENTS

TABLE OF CONTENTS (Concluded)

ENVIRONMENTAL ASSESSMENT OF REMEDIAL ACTION AT THE AMBROSIA LAKE URANIUM MILL TAILINGS SITE AMBROSIA LAKE, NEW MEXICO

U.S. DEPARTMENT OF ENERGY

ABSTRACT

This document assesses and compares the environmental impacts of various alternatives for remedial action at the Ambrosia Lake uranium mill tailings site located near Ambrosia Lake, New Mexico. The designated site covers 196 acres and contains 111 acres of tailings and some of the original mill structures. The Uranium Mill Tailings Radiation Control Act (UMTRCA), Public Law 95-604, authorizes the U.S. Department of Energy to clean up the site to reduce the potential health impacts associated with the residual radioactive materials remaining at the site and at associated properties off the site. The U.S. Environmental Protection Agency promulgated standards for the remedial action (40 CFR Part 192). Remedial action must be performed in accordance with these standards and with the concurrence of the Nuclear Regulatory Commission. The proposed action is to stabilize the tailings at their present location by consolidating the tailings and associated contaminated materials into a recontoured pile. A radon barrier would be constructed over the pile and various erosion protection measures would be taken to assure the long-term stability of the pile. Another alternative which would involve moving the tailings to a new location is also assessed in this document. This alternative would generally involve greater short-term impacts and costs but would result in stabilization of the tailings at an undeveloped location. The no action alternative is also assessed in this document.

For more information contact:

James R. Anderson
UMTRA Project Manager
U.S. Department of Energy
UMTRA Project Office
5301 Central Avenue, NE, Suite 1720
Albuquerque, New Mexico 87108
505/844-3941

LIST OF FIGURES

LIST OF TABLES

1.0 SUMMARY

1.1 PROJECT SUMMARY

The Ambrosia Lake tailings site is located approximately 20 air miles north of the town of Grants in McKinley County, New Mexico (Figure 1.1). The site is situated in the Ambrosia Lake valley in the Grants Uranium District. In the 1970s, the Grants Uranium District was one of the most active in the U.S., having between 38 and 45 mines in operation within a 50-mile radius of Grants, New Mexico. After the collapse of the domestic uranium market in the early 1980s, the majority of mines and support operations closed. Businesses that supported the mining industry were similarly adversely affected. By the end of 1986, only two mines were in operation. Both mines, which are located within six miles of the Ambrosia Lake site, employ about 235 workers. Ore from Chevron's Mt. Taylor mine is shipped to its mill in Panna Maria, Texas; the Homestake mining operation uses its mill approximately 10 miles northwest of Grants.

The topography of the area surrounding the Ambrosia Lake site consists of broad valleys separated by elongated mesas. Small ephemeral streams drain the immediate area toward the southwest.

The Ambrosia Lake area is semi-arid with annual precipitation less than 11 inches. Plant species common to the area include Russian thistle, squirreltail grass, and snakeweed. The dominant land uses are grazing and uranium mining. The closest town is San Mateo (unincorporated) approximately 15 air miles southeast. The immediate area surrounding the tailings site is very sparsely populated. The nearest residence is more than two miles away; approximately 60 people live within a six-mile radius.

The Phillips Petroleum Company built the Ambrosia Lake mill in 1957 and began operations in 1958. United Nuclear Corporation bought the mill in 1963 and ceased operations shortly thereafter. The Ambrosia Lake mill was designed to process uranium ores by a closed-circuit carbonate leach method. During milling operations, approximately three million tons of ore were processed to produce 6536 tons of uranium concentrate (FBDU, 1981).

The Ambrosia Lake tailings site consists of the tailings pile and the mill site. The existing tailings pile is roughly square in shape with a slightly concave top. Dikes composed of native soil and tailings have been constructed around the edges of the pile, but no other measures to stabilize the pile have been undertaken. The tailings pile covers approximately 111 acres and averages approximately 17 feet in depth. Approximately 2.7 million cubic yards of tailings are contained in the pile.

The mill site includes the main mill building, offices, a laboratory, garages, and other structures and equipment (Figure 1.2). The mill structures have been abandoned and are in poor repair.

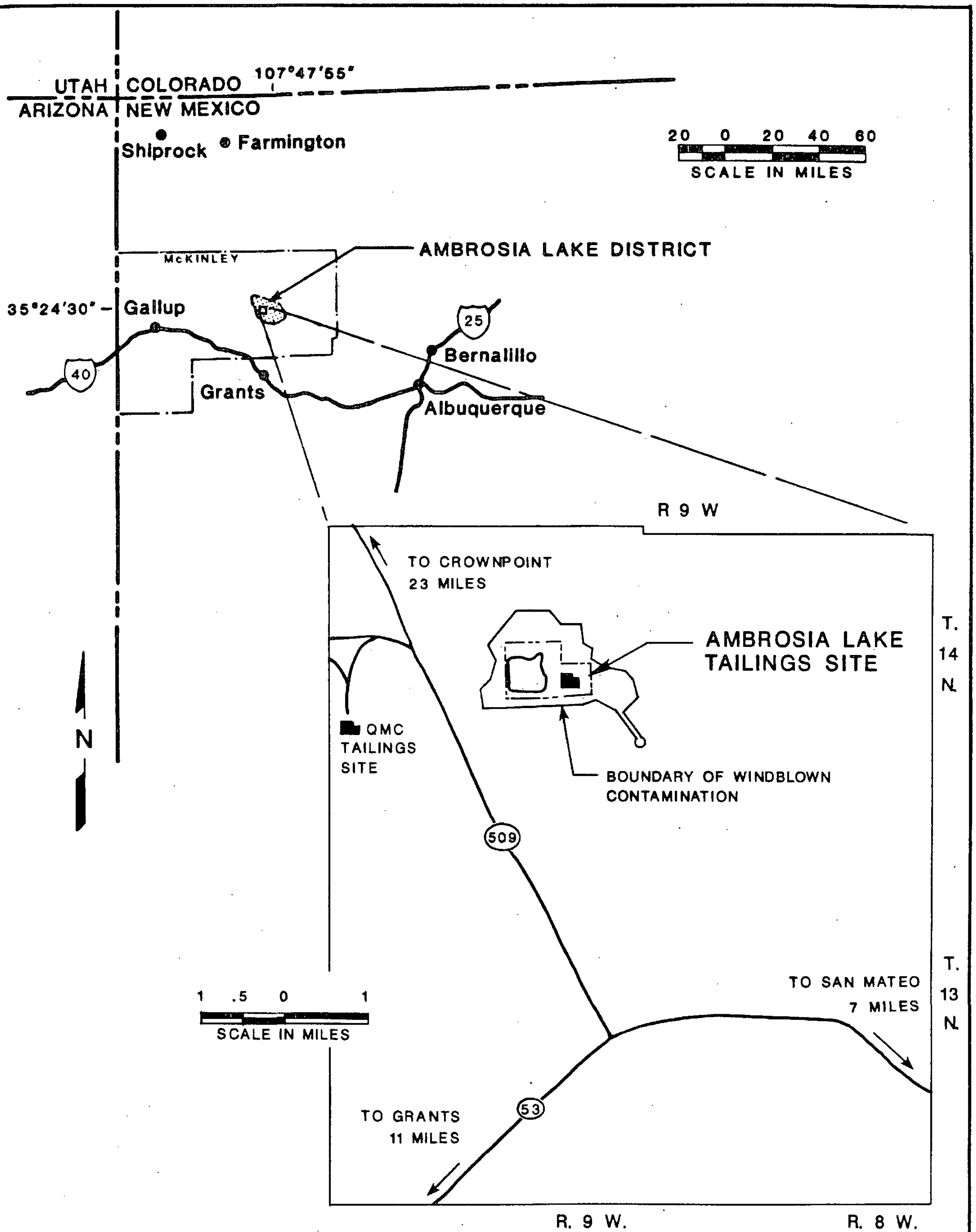


FIGURE 1.1 AMBROSIA LAKE SITE LOCATION

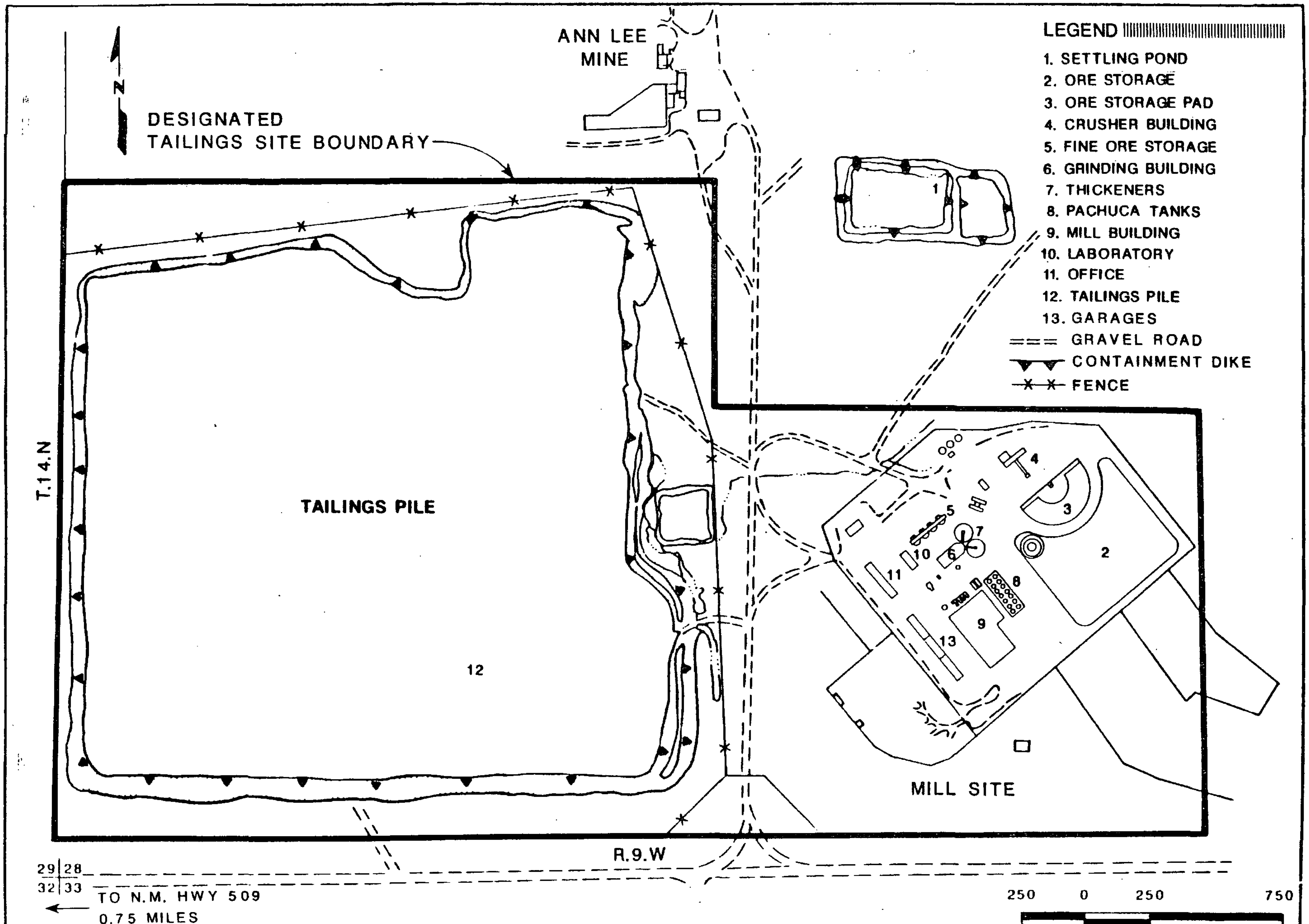


FIGURE 1.2 AMBROSIA LAKE TAILINGS SITE

Wind and water erosion have spread the contamination over approximately 570 acres surrounding the tailings pile both on and off the designated site (Figure 1.1). The main cause of erosion is from wind; however, surface water has caused some erosion of the dike on the eastern edge of the pile. The total volume of contaminated materials, including the tailings and contaminated soils beneath and around the tailings (i.e., windblown), is 4.6 million cubic yards.

Vicinity properties are properties that are located outside a designated tailings site boundary and that may have been contaminated by tailings dispersed by wind or water erosion or by removal by man before the potential hazards of the tailings were known. Vicinity properties are typically located by aerial radiological surveys or by on-site, mobile gamma ray scanning. Surveys of the Ambrosia Lake area resulted in the determination that there are no vicinity properties outside the tailings site and adjacent area contaminated by windblown tailings. Remedial action within the area of windblown contamination would be performed concurrently with cleanup of the tailings site. Environmental impacts from cleanup of windblown tailings are assessed in this document. The potential environmental impacts of remedial action at vicinity properties at other Uranium Mill Tailings Remedial Action (UMTRA) Project sites were previously assessed in a programmatic environmental report (DOE, 1985). Impacts to any vicinity properties associated with the Ambrosia Lake tailings outside the tailings site and adjacent area of windblown contamination that may be located prior to remedial action are expected to be similar to those assessed in the programmatic environmental report and are therefore not considered in this EA.

The principal potential hazard associated with the tailings results from the production of radon, a radioactive decay product of the radium contained in the pile. Radon, a radioactive gas, can diffuse through the pile and be released into the atmosphere where it and its radioactive decay products (radon daughters) may be inhaled by humans. Increased exposure to radon and its decay products over a long period of time will increase the probability that health effects (i.e., cancers) may develop in persons living and working near the pile. Exposure to gamma radiation, the inhalation of airborne radioactive particulates, the ingestion of contaminated food produced in the area around the tailings, and the ingestion of surface and ground waters contaminated by the tailings also pose potential hazards. If the tailings are not properly stabilized, erosion by wind or water or human removal of contaminated materials could spread the contamination over a much wider area and increase the potential for public health hazards.

The Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), Public Law 95-604 (PL95-604), authorized the U.S. Department of Energy (DOE) to perform remedial action at the Ambrosia Lake tailings site (as well as at many other sites) to reduce the potential public health impacts from the residual radioactivity remaining in the pile. The U.S. Environmental Protection Agency (EPA) promulgated standards (40 CFR Part 192) in March, 1983, for this remedial action.

The proposed remedial action for the Ambrosia Lake tailings is stabilization in place. All of the tailings and windblown contaminated soils would be consolidated with the existing tailings pile, and the resulting pile would be recontoured to have 20 percent sideslopes (five horizontal to one vertical) and a gently sloping top. The pile would then be covered with a layer of compacted earth to inhibit radon emanation and water infiltration. The top and sides of the pile would be covered with a layer of sand and rock to protect the pile against erosion, penetration by animals, and inadvertent human intrusion. Rubble and asbestos from demolition of the mill site would be disposed in the tailings pile in accordance with applicable State and Federal regulations. The top of the stabilized pile would average 50 feet above the surrounding terrain. Drainage swales would prevent surface runoff from concentrating on the pile. Areas disturbed by remedial action would be restored in accordance with applicable permits or approvals and released for unrestricted use.

The no action alternative would consist of taking no remedial action at the tailings site. The tailings would remain in their present location and condition and would continue to be susceptible to erosion and unauthorized removal and use by man.

Disposal of the tailings at the Section 21 alternate disposal site would involve moving all of the contaminated materials to a site approximately one mile north of the existing tailings site (Figure 1.3). This land is used primarily for low density livestock grazing. The site is approximately 2.5 miles from the nearest residence. The tailings would be placed in a partially below-grade pile and covered with compacted earth, sand, and rock; mill rubble would be buried below grade similar to stabilization in place. The existing tailings site would be restored and released for unrestricted use.

1.2 IMPACT SUMMARY

This section contains a quantitative listing of the short-term (i.e., during 18 months of remedial action) and long-term (i.e., post-remedial action) environmental impacts of the proposed action (Table 1.1) and a brief discussion of the major differences between the proposed action and the other alternatives. The impacts presented here are based on conservative impact assessment methods and represent a realistic upper limit of the severity of the potential impacts for stabilization in place.

No action alternative

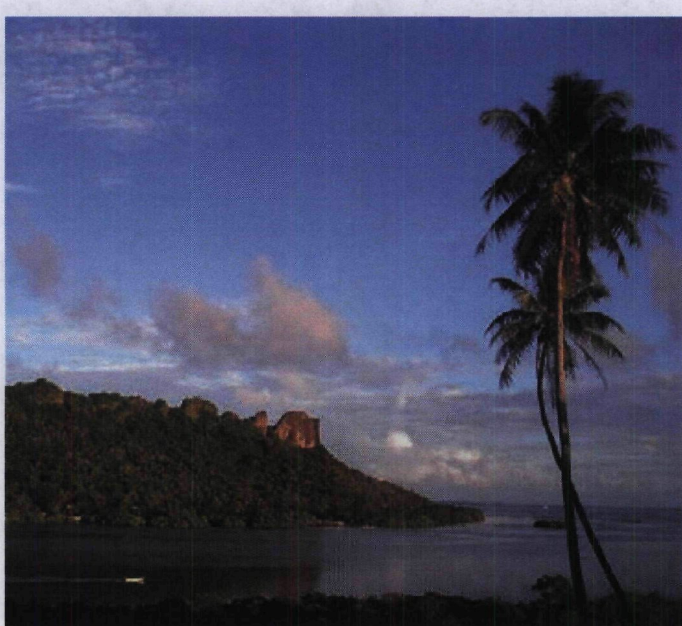
Selection of the no action alternative would not be consistent with the intent of Congress in UMTRCA (PL95-604) and would not result in the DOE's compliance with the EPA standards (40 CFR Part 192). This alternative would result in the continued dispersion of the tailings over a wide area by wind and water erosion, and the tailings would not be protected against unauthorized removal by humans. Continued dispersion and unauthorized removal and use of the tailings could cause radiological contamination of other areas and could result in greater public health impacts than those calculated for this alternative.

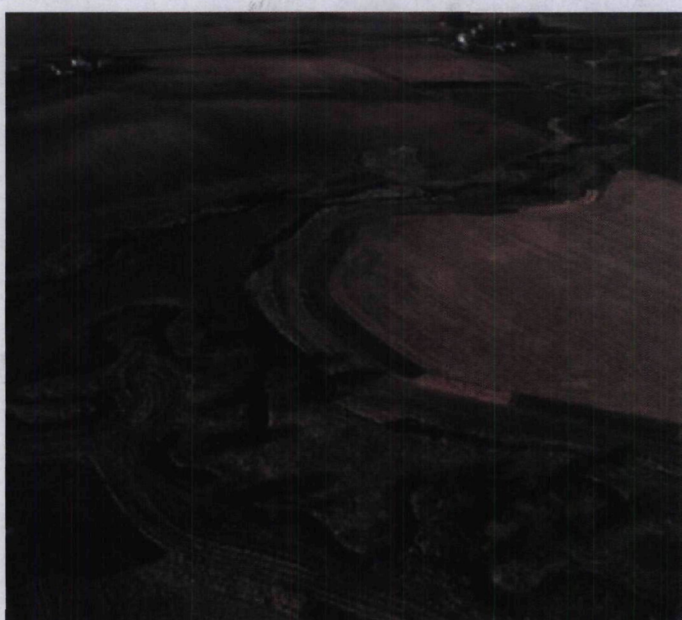
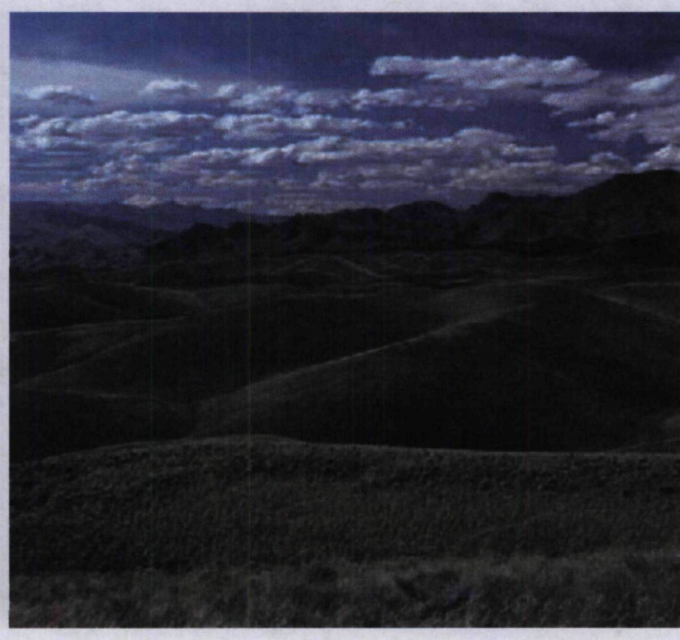
United States Department of Agriculture

Natural Resources Conservation Service

United States Department of Agriculture Handbook 296

Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin



more than 35 percent. Many of the soils are shallow or moderately deep to shale or sandstone bedrock. Most are well drained. Most are calcareous. The soils at the lower elevations generally have significant amounts of calcium carbonate, salts, and gypsum.

Biological Resources

This area has three major land resource units. These are the desert-salt desert zone, the semi-desert zone, and the upland-foothill zone.

The largest and most dominant unit is the desert-salt desert zone. This zone occurs at the lower elevations receiving less than 8 inches of annual precipitation (205 millimeters). The representative vegetation includes Castlevalley saltbush, Gardner's saltbush, mat saltbush, greasewood, shadscale, bud sagebrush, winterfat, Indian ricegrass, salina wildrye, and galleta. Cottonwood and willows grow along riparian zones.

The semi-desert zone occurs as a narrow 8- to 12-inch (205- to 305-millimeter) precipitation band. This zone has two vegetative subzones. The more extensive subzone includes Wyoming big sagebrush, black sagebrush, shadscale, fourwing saltbush, Mormon tea, Indian ricegrass, and galleta. The other subzone occurs mostly in the area of the San Rafael Swell in Utah. This subzone is similar to the other subzone but lacks Wyoming big sagebrush and has more Utah juniper trees. Wyoming big sagebrush and pinyon pine may occur but only as a few widely scattered plants.

The upland-foothill zone occurs as a 12- to 16-inch (305- to 405-millimeter) precipitation band. Utah juniper and pinyon pine forests are dominant in this zone. The representative vegetation includes Utah juniper, pinyon pine, Wyoming big sagebrush, black sagebrush, prairie junegrass, muttongrass, and needleandthread. Gambel oak, Utah serviceberry, antelope bitterbrush, mountain mahogany, and bluebunch wheatgrass grow at the higher elevations.

Some of the major wildlife species in this MLRA are coyote, kit fox, white-tailed prairie dog, white-tailed jackrabbit, pronghorn, mule deer, elk, American kestrel, sage grouse, turkey vulture, screech owl, mourning dove, piñon jay, common raven, sage sparrow, bald eagle, golden eagle, western rattlesnake, bullsnake, fence lizard, sagebrush lizard, Colorado pike minnow, razorback sucker, bonytail, and humpback chub.

Land Use

Following are the various kinds of land use in this MLRA:

- Cropland—private, 1%
- Grassland—private, 21%; Federal, 74%
- Forest—Federal, 1%
- Urban development—private, 1%
- Other—private, 1%; Federal, 1%

About three-fourths of this area is federally owned. Most of the area is used for recreation or livestock grazing. Different types of surface or sprinkler irrigation are used in many of the valleys. The major crops grown throughout the area are silage corn, grain corn, alfalfa, and small grains. Cantaloupe and melons are grown near Green River, Utah, and lettuce, onions, dry beans, peppers and other small vegetable crops are grown in the Grand Valley and Uncompahgre areas. Many tracts of rangeland and cropland have been, and are continuing to be, subdivided for community development.

The major soil resource concerns are salinity, sodicity, leaching of selenium and salts into surface and ground water supplies, irrigation-induced erosion, and subsidence resulting from gypsum dissolution. Wind erosion is a hazard on light textured soils during periods when annual crops are grown and during periods of plant germination. It also is a hazard in areas of salt-desert shrub communities. The main management concerns on rangeland are wind erosion, gully erosion, invasive species, and declining rangeland health. The main management concerns in cultivated areas include salinization, declining water tables, and inadequate supplies of irrigation water.

Conservation practices on rangeland generally include erosion control, fencing, development of watering facilities, brush management, rangeland seeding, and proper grazing management. Conservation practices on cropland include improvement of the efficiency of irrigation systems, irrigation water management, and crop residue management. Conservation practices on hayland and pasture include improvement of the efficiency of irrigation systems, irrigation water management, and forage harvest management. ■

35—Colorado Plateau

This area (shown in fig. 35-1) is in Arizona (56 percent), Utah (22 percent), New Mexico (21 percent), and Colorado (1 percent). It makes up about 71,735 square miles (185,885 square kilometers). The cities of Kingman and Winslow, Arizona, Gallup and Grants, New Mexico, and Kanab and Moab, Utah, are in this area. Interstate 40 connects some of these cities, and Interstate 17 terminates in Flagstaff, Arizona, just outside this MLRA. The Grand Canyon and Petrified Forest National Parks and the Canyon de Chelly and Wupatki National Monuments are in the part of this MLRA in Arizona. The Zion, Capitol Reef, Canyonlands, and Arches National Parks and the Grand Staircase-Escalante, Natural Bridges, and Hovenweep National Monuments are in the part in Utah. The Aztec Ruins, El Morro, El Malpais, and Chaco Canyon National Monuments and the Chaco Culture National Historic Park are in the part in New Mexico. The Dixie, Manti-La Sal, Kaibab, Prescott, Coconino, Sitgreaves, Apache, and Cibola National Forests are in this MLRA. "Four Corners," the only place in America where four State boundaries meet at one point, is in this area. The Navajo and Hopi Nations make up a significant portion of this MLRA in eastern Arizona, western New Mexico, and southern Utah. Other Native American Nations in Arizona

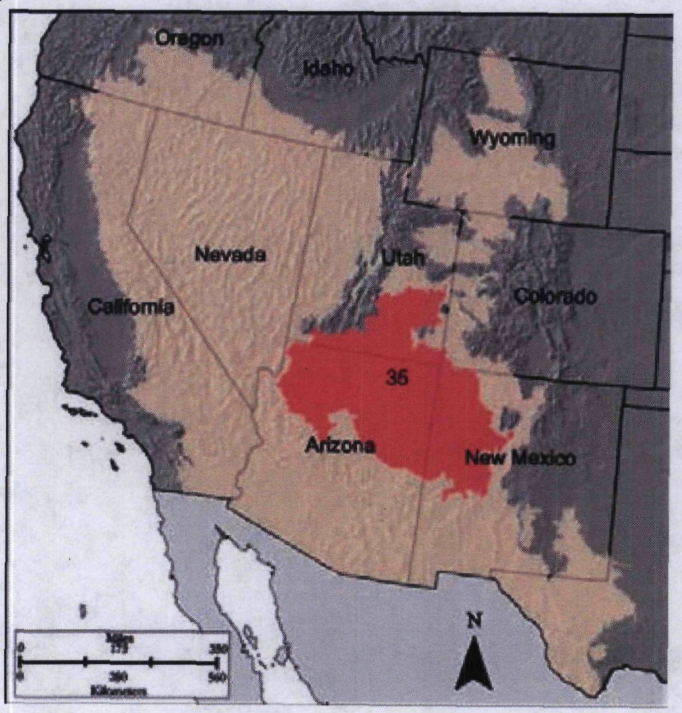


Figure 35-1: Location of MLRA 35 in Land Resource Region D.

include the Zuni, Havasupai, Hualapai, and Kaibab. The Ramah Nation and a small part of the Acoma Nation are in the part of this MLRA in New Mexico. Almost all of the part of this MLRA in Colorado is in the Ute Mountain Nation.

Physiography

This area is in the Colorado Plateaus Province of the Intermontane Plateaus. Different parts of this MLRA are in five of the six sections within the Colorado Plateaus Province. Most of the eastern and central parts of the MLRA are in the Navajo Section. The second largest part, to the west of the Navajo Section, is in the Grand Canyon Section. The northernmost part is in the Canyon Lands Section, and the northwest corner is in the High Plateaus of Utah Section. The southeast corner is in the Datil Section. In general, the surface consists of gently sloping to strongly sloping plains. Volcanic plugs that rise abruptly above the plains, steep scarps, or deeply incised canyons interrupt the surface of the plains. In most areas elevation is 4,250 to 4,950 feet (1,295 to 1,510 meters). Mt. Trumbull, on the north rim of the Grand Canyon, however, reaches a height of 8,028 feet (2,448 meters), and Navajo Mountain, on the Utah-Arizona State line, reaches a height of 10,388 feet (3,167 meters).

The extent of the major Hydrologic Unit Areas (identified by four-digit numbers) that make up this MLRA is as follows: Little Colorado (1502), 34 percent; San Juan (1408), 21 percent; Lower Colorado-Lake Mead (1501), 19 percent; Upper Colorado-Dirty Devil (1407), 14 percent; Rio Grande-Elephant Butte (1302), 4 percent; Salt (1506), 3 percent; Upper Colorado-Dolores (1403), 3 percent; and Lower Green (1406), 2 percent. The Colorado River and its tributary in Arizona, the Little Colorado River, are in this MLRA. The Glen Canyon Dam, on the Colorado River (Lake Powell), also is in this area. The Mancos and McElmo Rivers in Colorado are tributaries to the San Juan River in New Mexico. Parts of the Virgin, Sevier, Escalante, Otter, Dirty Devil, Green, and Paria Rivers are in the part of this MLRA in Utah. Rio Puerco is in the part in New Mexico.

Geology

This area is part of the Colorado Plateau, an area that has been structurally uplifted. Rivers flowing across the area cut down into the bedrock as it was being uplifted, resulting in spectacular geologic scenery. Areas of shale, sandstone, limestone, dolomite, and volcanic rock outcrop are extensive. Rocks representing almost the entire geologic timespan are exposed from the bottom of the Grand Canyon up to the present-day surface. Quaternary and Tertiary lava flows occur on the surface in the southwest part of this area. Older flows cap plateaus and mesas, and isolated volcanic cones and eroded volcanic necks occur throughout the area.

Climate

The average annual precipitation is 6 to 18 inches (150 to 455 millimeters) in almost all of this area, but it is less than 5 inches (125 millimeters) in a few basins on the west edge of the area. The highest average annual precipitation, 30 inches (760 millimeters), occurs in a few isolated mountains in southern Utah and near the Arizona-New Mexico State line. About half of the precipitation falls from July through September. April, May, and June are the driest months. Most of the rainfall occurs as high-intensity, convective thunderstorms late in summer. Light snow falls in winter, but it does not remain on the ground very long. The average annual temperature is 36 to 66 degrees F (2 to 19 degrees C), decreasing to the north and at the higher elevations. The freeze-free period averages 215 days and ranges from 105 to 320 days, decreasing in length to the north and at the higher elevations.

Water

Following are the estimated withdrawals of freshwater by use in this MLRA:

Public supply—surface water, 0.4%; ground water, 2.7%
Livestock—surface water, 5.7%; ground water, 2.0%
Irrigation—surface water, 34.9%; ground water, 12.9%
Other—surface water, 24.3%; ground water, 17.2%

The total withdrawals average 560 million gallons per day (2,120 million liters per day). About 35 percent is from ground water sources, and 65 percent is from surface water sources. Water is scarce throughout the area. Many streams and rivers are ephemeral. The Little Colorado River drains the largest segment of the area, but its flow is intermittent. Water is stored in small reservoirs for irrigation purposes, but supplies are often inadequate. Some irrigation water is obtained from erratic streamflow. The surface water is suitable for almost all uses. A high sediment load is the primary water-quality problem.

The San Juan River basin in the part of this area in northwest New Mexico has the highest streamflow volume in the State. It is one area that relies almost entirely on surface water. The Navajo Reservoir and a few smaller reservoirs store water for use by residents in this area. The river water is of exceptional quality. It is suitable for a cold-water fishery. High salt and sediment loads from ephemeral tributaries on the south side of the basin degrade the river water.

Ground water is the primary source of drinking water in many areas. In places some irrigation water is obtained from deep wells. Ground water occurs in the Coconino, Navajo, and Dakota Sandstone aquifers. It is soft to hard water and generally contains less than 300 parts per million (milligrams per liter) total dissolved solids in Arizona. Median levels of total dissolved solids are closer to 1,000 parts per million (milligrams per liter) in Utah and New Mexico. Lower levels of total dissolved solids and fresher water occur near the recharge zones for these consolidated sediments. Very salty water occurs at depth and away from the recharge zones. Highly mineralized water leaks into these aquifers from older and younger marine sediments above and below the sandstone aquifers.

Some irrigation water is pumped from the valley fill in the San Juan River basin. It has a higher salt content than the river water but otherwise is very similar in quality. Use of the valley fill water is limited because seepage of salty water from the adjacent rocks containing soluble salts increases the sodium sulfate content.

Soils

The dominant soil orders in this MLRA are Alfisols, Aridisols, Entisols, and Mollisols. The soils in the area dominantly have a mesic soil temperature regime; an aridic soil moisture regime or an ustic moisture regime that borders on aridic; and carbonatic, mixed, or smectitic mineralogy. They generally are very shallow to very deep, well drained or somewhat excessively drained, and loamy or clayey.

Haplustalfs (Lykorly series) and Haplargids (Penistaja series) formed in mixed eolian deposits and alluvium on mesas, cuestas, hills, bajadas, and fan terraces. Calciargids (Millett series) formed in alluvium on fan terraces, piedmonts, and plains. Haplocalcids formed in mixed residuum and colluvium on benches, hills, and ridges (Mellenthin series) and in eolian deposits over alluvium (Winona series). Haplocambids formed in mixed eolian deposits and alluvium on mesas, cuestas, hills, and fan terraces (Begay series) and in alluvium on plateaus and mesas (Epikom series). Ustorthents formed in mixed residuum and colluvium on mesas and mountains (Menefee series) and in mixed eolian deposits and alluvium on ridges, hills, and mesas (Vessilla series). Torriorthents formed in mixed alluvium and residuum (Moenkopie series) and in mixed residuum and colluvium (Rizno series) on mesas, hills, benches, cuestas, and plateaus. Torripsamments (Sheppard series) formed in eolian deposits on benches, dunes, and terraces. Argiustolls (Luzena series) formed in residuum and colluvium on mesas, hills, and mountains.

Biological Resources

This area supports desert shrub and woodland vegetation. At high elevations, pinyon-juniper woodland and sagebrush have an understory of galleta, blue grama, black grama, and western wheatgrass. Galleta grass, alkali sacaton, Indian ricegrass, bottlebrush squirreltail, and needlegrasses intermixed with fourwing saltbush and winterfat are at the lower elevations. Greasewood and shadscale are part of the plant community on salty soils. Blackbrush may be dominant at the lower elevations.

Some of the major wildlife species in this area are elk, mule deer, antelope, mountain lion, coyote, fox, bobcat, badger, skunk, rabbit, prairie dog, bats, eagles, hawks, owls, crow, woodpecker, bluebird, and swallow.

Land Use

Following are the various kinds of land use in this MLRA:

Cropland—private, 1%
Grassland—private, 48%; Federal, 27%
Forest—private, 8%; Federal, 6%
Urban development—private, 1%
Water—private, 1%
Other—private, 7%; Federal, 1%

About one-third of this area is federally owned. About three-fourths is rangeland. The rangeland is grazed by sheep and cattle. About 1 percent of the area, along the valleys of the major streams, is irrigated cropland. Alfalfa, small grains for hay, and corn for silage are the chief crops. Less than one-tenth of the area in scattered small tracts on Indian reservations is dry-farmed. Corn is the chief crop in the dry-farmed areas. More than one-tenth of the area is juniper and pinyon-juniper woodland. Firewood and pinyon nuts are products of this woodland, which also is grazed by cattle and sheep. If the areas are overgrazed, juniper invades the grassland. Severe gullying, overgrazing, and the lack of a dependable water supply are land use problems. Because of the mild climate and nearby recreational opportunities, the irrigated cropland near towns, such as Moab and Kanab, is being converted to housing developments.

The major soil resource concerns are maintenance of the content of organic matter in the soils, soil productivity, wind erosion, water erosion, salinity, and sodicity. These factors and the low rainfall result in soils that have little or no resilience after disturbance and a very low tolerance for soil loss by erosion.

Conservation practices on rangeland generally include brush management, rangeland seeding, prescribed grazing, prescribed burning, fencing, development of watering facilities, and erosion control. Conservation practices on cropland and hayland are crop rotation, crop residue management, minimum tillage, nutrient and pest management, land leveling, ditch lining, irrigation water management, soil salinity management, and pasture and hayland management. ■

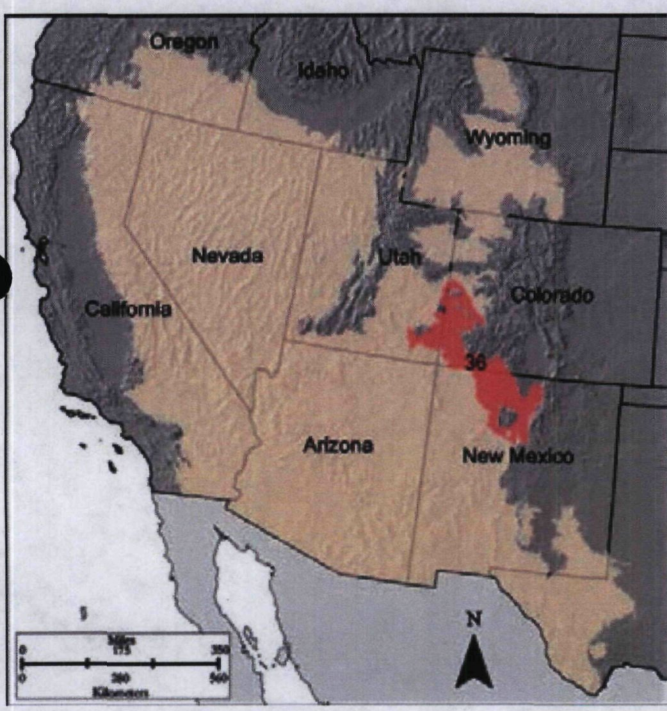


Figure 36-1: Location of MLRA 36 in Land Resource Region D.

36—Southwestern Plateaus, Mesas, and Foothills

This area (shown in fig. 36-1) is in New Mexico (58 percent), Colorado (32 percent), and Utah (10 percent). It makes up about 23,885 square miles (61,895 square kilometers). The major towns in the area are Cortez and Durango, Colorado; Santa Fe and Los Alamos, New Mexico; and Monticello, Utah. Grand Junction, Colorado, and Interstate 70 are just outside the northern tip of this area. Interstate 25 crosses the middle of the area, and U.S. Highway 550 runs along the southwest boundary of the area in New Mexico. Mesa Verde National Park and the Bandelier, Hovenweep, Natural Bridges, Yucca House, and Colorado National Monuments are in the area. Many Indian reservations are in this MLRA. The largest are the Southern Ute, Ute Mountain, and Jicarilla Apache Indian Reservations. Also in the area are the Cochiti, Jemez, Nambe, Navajo, Picuris, Pojoaque, San Felipe, San Ildefonso, San Juan, Sandia, Santa Ana, Santa Clara, Santa Domingo, Taos, Tesuque, and Zia Indian Reservations.

Physiography

This area is on the Intermontane Plateaus. It is mainly in the Canyon Lands and Navajo Sections of the Colorado Plateaus Province, is partly in the Mexican Highland Section of the Basin and Range Province, and extends marginally into the Southern Rocky Mountains Province. Landforms in most areas are controlled by the underlying sedimentary rock formations, but fluvial landforms are in the Rio Grande rift basin at the southeastern extent of the MLRA. Elevation commonly is 4,600 to 8,500 feet (1,400 to 2,590 meters). It generally is highest (as much as 9,300 feet, or 2,835 meters) in areas of the foothills and high mesas that border the Southern Rocky Mountains. Relief generally is less than 1,500 feet (455 meters).

The extent of the major Hydrologic Unit Areas (identified by four-digit numbers) that make up this MLRA is as follows: Rio Grande-Elephant Butte (1302), 47 percent; San Juan (1408), 32 percent; Upper Colorado-Dolores (1403), 15 percent; Gunnison (1402), 4 percent; Colorado Headwaters (1401), 1 percent; and Upper Colorado-Dirty Devil (1407), 1 percent. The upper reaches of the Rio Grande and San Juan Rivers and their tributaries are in the part of this MLRA near the Colorado and New Mexico State lines. Rio Puerco and Rio Chama are in the part of the MLRA in New Mexico. The Dolores and San Miguel Rivers are in the part in Colorado, and a short reach of the Colorado River crosses this MLRA near the Utah and Colorado State lines.

Geology

Most of the area is characterized by generally horizontal beds of Jurassic, Cretaceous, and Tertiary sedimentary rocks. Representative formations are the Morrison Formation; Dakota Sandstone, Mancos Shale, Cliff House Sandstone, and other members of the Mesa Verde Group; the Animas Formation; and the San Jose Formation. The sedimentary rocks have been eroded into plateaus, mesas, hills, and canyons. Thick deposits of eolian material of Pleistocene age mantle the top of the mesas in some areas. Small areas of Tertiary and Quaternary volcanic rocks, including cinder cones and lava flows, are in the Rio Grande rift basin in New Mexico. Wide valleys in the rift basin have accumulated deep alluvial sediments, and fan remnants are common.

Climate

The average annual precipitation in this area ranges from 8 to 31 inches (205 to 785 millimeters). It is dominantly 12 to 20 inches (305 to 510 millimeters). Much of the rainfall occurs as convective storms in late summer; about 20 to 35 percent of the total precipitation falls in July and August. This proportion increases from north to south within the area. About 15 to 25 percent of the precipitation is snow. Snowpacks are generally light and not persistent throughout the winter, except at the higher elevations. The average annual temperature ranges from 37 to 56 degrees F (3 to 14 degrees C). The freeze-free period averages 160 days and ranges from 105 to 210 days. The shortest freeze-free periods occur in the northern part of the area and at high elevations.

Water

Following are the estimated withdrawals of freshwater by use in this MLRA:

Public supply—surface water, 2.1%; ground water, 3.6%
Livestock—surface water, 0.6%; ground water, 0.1%
Irrigation—surface water, 78.7%; ground water, 11.1%
Other—surface water, 0.1%; ground water, 3.7%

The total withdrawals average 1,130 million gallons per day (4,275 million liters per day). About 18 percent is from ground water sources, and 82 percent is from surface water sources. Water commonly is scarce in areas away from the major streams. The Dolores, Animas, and San Juan Rivers, which are perennial streams in the northern end of the area, are major sources of irrigation water. The headwater streams of the Rio Grande also have water of excellent quality. The Navajo, Heron, and El Vado Reservoirs store water for irrigation and recreation in this area. The San Juan River is a high-quality, cold-water fishery stream in northwestern New Mexico. It is used for municipal and industrial supplies as well as irrigation. High salt loads from southern tributary streams affect water quality in this area. The quality of some surface water has been degraded by the effects of upstream mining activities in the late 1800s. This mining occurred mainly in the upper reaches of the streams outside this MLRA.

Ground water is the primary source of drinking water in many areas. In places some irrigation water is obtained from deep wells. Cretaceous and Jurassic sediments (Dakota and Morrison Formations and Entrada Sandstone) provide some ground water of variable quality in southwestern Colorado. The ground water in New Mexico is in Tertiary sandstone and in the older sediments. It is soft to hard water and generally exceeds the national drinking water standard for total dissolved solids. Median levels of total dissolved solids are close to 1,000 parts per million (milligrams per liter) in New Mexico. Because of high sodium and sulfate levels, the water is of limited use for drinking in many areas. Fresher water with lower levels of total dissolved solids is near the recharge zones for these consolidated sediments. Very salty water is at depth and away from the recharge zones. Highly mineralized water leaks into these aquifers from older and younger marine sediments above and below the sandstone aquifers.

Some irrigation water is pumped from the valley fill in the larger river valleys. It has a higher salt content than the river water but otherwise is very similar in quality. Seepage of salty water from the adjacent rocks containing soluble salts can increase the sodium sulfate content, which limits the use of the valley fill water.

Soils

The dominant soil orders in this MLRA are Alfisols, Inceptisols, Mollisols, Entisols, and Aridisols. The soil moisture regime is mainly ustic, but an aridic regime that is marginal to ustic occurs in some areas. The soil temperature regime is mesic or frigid. Mineralogy is dominantly mixed or smectitic.

In the warmer areas, shallow Ustorthents (Menefee series) formed in residuum on shale hills and mesas. Shallow Haplustalfs (Arabrab series) and Torriorthents (Rizno series) formed in material weathered from sandstone on mesas, hills, and cuestas. Moderately deep, loamy Haplargids (Gapmesa series) and very deep, loamy Haplustalfs (Orlie series) formed in slope alluvium derived from sandstone and shale on mesas or fan remnants. Very deep, clayey Haplustepts (Roques series) formed in alluvium derived from shale on valley sides. Very deep, silty Haplustalfs (Cahona and Wetherill series) formed in eolian material on hills and mesas.

In the cooler areas, very deep, clayey Haplustalfs (Goldbug series) formed in slope alluvium derived from sandstone and shale on hills and mesas. Shallow Argiustolls (Fivepine series) formed in slope alluvium and residuum derived from sandstone. Moderately deep Argiustolls (Nortez series) formed in eolian material derived from sandstone on hills and mesas.

Biological Resources

The potential vegetation is grass and sagebrush at the lower elevations. Pinyon-juniper woodland and ponderosa pine forests are at mid elevations. Forests of Rocky Mountain Douglas-fir and white fir are at the higher elevations. Some common plants are Wyoming big sagebrush, western wheatgrass, galleta, needleandthread, and blue grama at the lower elevations; twoneedle pinyon, Utah juniper, Indian ricegrass, mountain mahogany, ponderosa pine, Gambel oak, Arizona fescue, and muttongrass at mid elevations; and Rocky Mountain Douglas-fir, white fir, mountain muhly, common snowberry, Parry's oatgrass, and mountain brome at the higher elevations.

Some of the major wildlife species in this area are mule deer, elk, coyote, black bear, mountain lion, black-tailed jackrabbit, Gunnison's prairie dog, badger, piñon jay, black-billed magpie, mountain chickadee, red-breasted nuthatch, white-breasted nuthatch, collared lizard, fence lizard, and western rattlesnake. Reservoirs and rivers provide most of the fish habitat in this area. The ones at the higher elevations have cold-water species, such as rainbow trout and brown trout, and the ones at the lower elevations may have warm-water species, such as bass, bluegill, crappie, and catfish.

Land Use

Following are the various kinds of land use in this MLRA:

Cropland—private, 3%
Grassland—private, 41%; Federal, 39%
Forest—private, 7%; Federal, 5%
Urban development—private, 2%
Other—private, 3%

Nearly all of this area supports natural vegetation and is used as grazing land or forestland. Cropland also is a significant land use. Where irrigation water is available, irrigated crops, such as wheat, barley, beans, oats, alfalfa, and hay, are grown. An area in Colorado and Utah is used as nonirrigated cropland. The major crops grown on this nonirrigated cropland are beans and winter wheat. The pinyon-juniper woodlands are a source of fuel wood. At the higher elevations, commercial timber is harvested, principally ponderosa pine and Rocky Mountain Douglas-fir. Some urban development is occurring in the vicinity of Santa Fe.

The major soil resource concerns are wind erosion, water erosion, maintenance of the productivity of the soils, and management of soil moisture. Conservation practices on cropland generally include crop residue management, minimum tillage, and irrigation water management. Proper grazing use is a concern on grazing lands. The primary concerns in timbered areas are controlling erosion along roads and skid trails and minimizing surface compaction during timber harvesting. ■

38—Mogollon Transition

This area (shown in fig. 38-1) is in Arizona (81 percent) and New Mexico (19 percent). It makes up about 18,985 square miles (49,195 square kilometers). The cities of Globe and Prescott, Arizona, and Silver City, New Mexico, occur in this MLRA. U.S. Highway 180 crosses this area in New Mexico, and Interstate 17 crosses the middle of the area in Arizona. Parts of the Prescott, Tonto, Gila, and Cibola National Forests are in this area. The MLRA has numerous wilderness areas and national forests. The Tuzigoot and Montezuma Castle National Monuments and the Hualapai, Yavapai, Camp Verde, Lower Camp Verde, and San Carlos Indian Reservations are in the part of this area in Arizona.

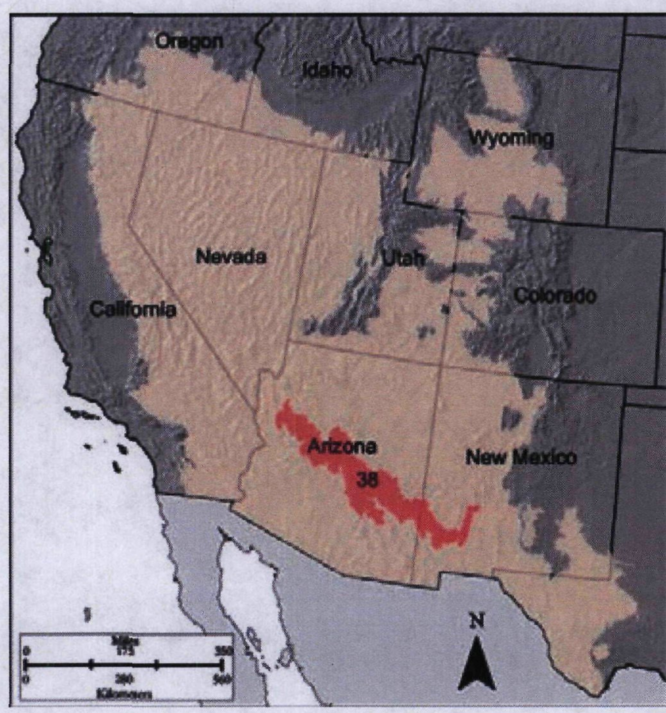


Figure 38-1: Location of MLRA 38 in Land Resource Region D.

Physiography

This area is in the Mexican Highland Section of the Basin and Range Province of the Intermontane Plateaus. The area consists of canyons and structural troughs and valleys. Examples of the many mountain ranges in the area are the Pinal, Sierra Ancha, and Mazatzal Mountains in Arizona and the Big Burro and Mimbres Mountains in New Mexico. Elevation ranges from 3,000 to 5,500 feet (915 to 1,675 meters) in most areas and from 5,100 to 7,500 feet (1,555 to 2,285 meters) in the mountains.

The extent of the major Hydrologic Unit Areas (identified by four-digit numbers) that make up this MLRA is as follows: Salt (1506), 37 percent; Upper Gila (1504), 25 percent; Lower Colorado (1503), 14 percent; Lower Gila (1507), 9 percent; Rio Grande-Mimbres (1303), 8 percent; and parts of many other hydrologic units, 7 percent. The Verde, Black, and Salt Rivers are tributaries to the Gila River in this MLRA. A reach of the Verde River has been designated a National Wild and Scenic River in Arizona.

Geology

Most of this area is covered by deep alluvium washed in from the adjacent mountains. These deposits of silt, sand, and gravel are very young in the present-day drainages and much

UMTRA - DOE/AL .0000

AMB RAP

United States Department of Energy

Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico

Final

Volume II: Appendices D and E

Appendix B of the Cooperative Agreement No. DE-FC04-85AL20533

November 1991

Uranium Mill Tailings Remedial Action Project

APPENDIX D
SITE CHARACTERIZATION

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Concluded)

Addenda D1 through D3 have not been reproduced in this version of the RAP. They were previously published in the May 1987 Preliminary Final RAP.

LIST OF FIGURES

LIST OF FIGURES (Concluded)

LIST OF PLATES

LIST OF TABLES

D.1 INTRODUCTION

The Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 (PL95-604), requires the U.S. Department of Energy (DOE) to assess the degree of radiological contamination at the sites of certain former uranium mill operations and to conduct remedial actions "to stabilize and control such tailings in a safe and environmentally sound manner and to minimize or eliminate radiation health hazards to the public." This appendix summarizes and is an assessment of the present conditions and available data at the Ambrosia Lake inactive uranium mill site near Grants, New Mexico.

For ease in reading, figures and tables are grouped at the end of each section, figures first, in this appendix.

D.3 RADIATION DATA

D.3.1 PURPOSE

Background radiation levels must be established for the designated site and surrounding areas so that construction impacts on the environment can be assessed and the levels of radiation and contamination associated with the designated site can be compared to background. Knowledge of the radium content of the pile, off-site soils, and subsurface pile soils is necessary to design the excavation and pile cover. Groundwater sample data can be used to determine impacts due to contaminant migration from the tailings pile. Air concentration and gamma-ray exposure rate measurements aid in determining limits of contamination and potential health hazards. Finally, the building contamination data are necessary for decontamination/demolition planning activities.

D.3.2 BACKGROUND RADIATION DATA

Gamma-ray exposure rates, one meter above the ground, and surface soil samples were taken by Oak Ridge National Laboratory (ORNL) in 1980; sampling locations and results obtained are given in Table D.3.1 (Haywood et al., 1980). Based on these data, an average background gamma exposure rate of 11 microR/hr and an average Ra-226 soil concentration of 1.0 pCi/g were obtained (Haywood et al., 1980). Gamma-ray exposure rates were measured using energy compensated Geiger-Mueller (G-M) detectors.

Although taken in the general region of the state of New Mexico in which the Ambrosia Lake site is located, the values obtained from these background locations are probably significantly smaller than the background value near the site. This is primarily due to the influence of uranium mining and milling in the Ambrosia Lake area. The results from an aerial radiological survey conducted in August, 1981, by EG&G are shown in Figure D.3.1. Elevated gamma exposure rates due to mining and milling activities are superimposed on a background field which ranges from about 14 to 19 microR/hr.

No background Rn-222 sample values are available from the Ambrosia Lake site. Although some 24-hour baseline samples were collected (FBDU, 1981) up to three miles from the Phillips/UNC site, none were less than 2.9 pCi/l. This was the result of the intense mining and milling activity throughout the valley. The results of Rn-222 monitoring (FBDU, 1981) at the Ambrosia Lake site are presented in Figure D.3.2. Natural background radon concentrations in undisturbed areas with similar geologic settings as Ambrosia Lake have been measured by several investigators and average 0.19 $\pm$ 0.02 pCi/l (NMEID, 1985; Millard and Baggett, 1984).

Baseline concentrations of radioactive air particulates in the Ambrosia Lake area have been measured one mile west of the existing tailings site. Concentrations for the principle radionuclides of concern averaged 1.1 femtocuries per cubic meter (fCi/m^3) for U-238, 1.1 fCi/m^3 for U-234, 3.1 fCi/m^3 for Th-230, and 3.3 fCi/m^3 for Ra-226 from 26 months of continuous air sampling (NMEID, 1986a). Average concentrations for air particulates from 25 months of continuous air sampling in an undisturbed background location by San Mateo were 0.4 fCi/m^3 for U-238, 0.5 fCi/m^3 for U-234, 0.3 fCi/m^3 for Th-230, and 0.7 fCi/m^3 for Ra-226 (NMEID, 1986a).

Baseline radioactivity levels in soils typical of the Ambrosia Lake area which were not influenced by the tailings pile have been established as 1.2 $\pm$ 0.7 pCi/g for Ra-226, 1.0 $\pm$ 1.0 pCi/g for Th-230, and 3.0 $\pm$ 1.0 ppm for natural uranium (2.0 $\pm$ 0.7 pCi/g) (BFEC, 1985a). Background concentrations of Ra-226 in soils from areas not influenced by uranium mining and milling averaged 0.57 $\pm$ 0.08 pCi/g (NMEID, 1985), and 0.51 $\pm$ 0.09 pCi/g for Th-230 (NMEID, 1986a).

D.3.3 RADIONUCLIDE CONTENT OF THE PILE

The isotopes which have been analyzed for soil concentration are natural uranium and Ra-226. Concentrations of other isotopes may be estimated based on the abundance of these radionuclides and the assumption of secular equilibrium. Radionuclide concentration values reported herein are based on the statistically designed drilling and sampling program of Mountain States Research and Development (MSRD, 1982). Additional radiological characterization using MSRD samples was conducted by Sandia National Laboratories (SNL, 1982) and Bendix Field Engineering Corporation (BFEC, 1985a).

MSRD (1982) found an average of 0.0132 percent U_3O_8 in the tailings pile, corresponding to 37 pCi/g U-238 based on 106 boreholes sampled at a vertical interval of 2.5 feet. This concentration is based on the most complete data available.

The Ra-226 concentration in and below the pile averaged 455 pCi/g based on 407 samples from the 106 boreholes drilled by MSRD. Based on a pile volume of 3.437×10^6 cy, the total Ra-226 activity is 1795 Ci. Results of Ra-226 analyses performed by BFEC (1985a) and by SNL (1982) were input into a computer model which generated the above estimates. Resultant Ra-226 data appear in Table D1.2.1, Addendum D1. A description of the computer model along with detailed results are also presented.

D.3.4 RADON FLUX

Radon flux measurements made in 1976 and 1980 (FBDU, 1981) are indicated in Figure D.3.3. These values represent 12-hour averages using the charcoal canister technique. As short-term averages, their comparison to an annual average must be done in light of the variability of radon flux with moisture content, barometric pressure, and other meteorological parameters. The average of all measurements on the pile is 128.6 pCi/m^2s.

D.3.5 SUBPILE CONTAMINATION

A total of 312 samples taken by MSRD were derived at or below the physical interface between the tailings and underlying soil. The samples were analyzed by SNL for Ra-226 content. The analytical method employed placed the split-barrel sample in a shielded sodium iodide detector assembly where the Ra-226 content of the lower 10 inches of sample was estimated. These values are shown in the seventh column of Table D1.2.1, Addendum D1.

At the time of the split-barrel sampling, the drilling supervisor inspected the samples as they were extracted to determine the depth of the physical interface. This depth was based on visual and textural changes from the tailings material to the subbase material. Estimates of the depth to the physical interface are listed in the third column of Table D1.2.1, Addendum D1.

By inspection of the SNL Ra-226 concentration estimates, the depth at which 15 pCi/g Ra-226 is reached can be estimated in 80 percent of the boreholes. The SNL data are insufficient to provide an objective estimate in the remaining 20 percent of the holes. The depths to the 15 pCi/g concentration are listed in column 8 of Table D1.2.1, Addendum D1. The average depth below the tailings pile from the physical interface to the 15 pCi/g concentration is 4.76 feet. This value was added to the physical interface depth for boreholes where data did not allow an objective determination of the depth to the 15 pCi/g concentration.

D.3.6 GAMMA RADIATION

The radiological characteristics of the Ambrosia Lake site are extremely complex. The designated site is in the center of the Ambrosia Lake Mining District within the Grants Mineral Belt. Mining and milling activities around the site extended for two to three miles in virtually all directions but have reduced significantly in recent years. Because of the extensive uranium development in the area, the areal extent of contamination in excess of the EPA standards is very large. The contribution to total contamination due to the operation of the inactive Phillips/UNC facility is very difficult to separate from the contamination due to the other facilities and activities in the area.

An aerial radiological survey (EG&G, 1981) was conducted in August, 1981. Figure D.3.1 is reproduced from the aerial survey and shows the average values of gamma radiation fields surrounding the site. The 5 pCi/g level of radium contamination corresponds to the lower end of the range indicated by the letter "C" or 18 to 19 microR/hr. The mill complex and ore storage area correspond to the "F" field 2000 feet east of the pile. The small "F" area about 2000 feet south of the south-east corner of the pile corresponds with the location of Kerr-McGee's Section 33 mine.

The "F" area 4000 to 6000 feet east of the mill yard represents the UNC Section 27 mine. There are several roads between the mine and the Phillips/UNC mill which exhibit significantly elevated gamma levels. This is a result of ore being transported along these routes to the Phillips/UNC mill. A heap leach pile covering two to three acres lies to the east-southeast of the mill yard area 2000 feet distant. There are several large diameter pipes connecting the mill yard area to this pile, indicating that its presence is likely due to the operation of the Ambrosia Lake facility. Both the mine and heap leach pad are well beyond the designated site boundary.

An additional feature which is contaminated and related to the facility is a canal which extends from the mill yard to the southeast about 6000 feet, where it joins other canals from other mines and mills at the lagoon called Voght Tank. Whether the contamination in this canal system is due to contaminated discharges from the site is unknown. Additionally, the contribution of contamination due to each facility connected by the canal system is unknown.

Primary access roads crossing the valley are contaminated due to past mining activity. Contamination along these roads extends almost 1000 feet to either side. The potential for sources other than the Phillips/UNC tailings to have contributed to contamination around the designated site is unknown. This is particularly true for the elevated readings indicated in Figure D.3.1 for the area southwest of the pile to New Mexico Highway 509. A radiological survey to define the limit of contamination attributable to the Phillips/UNC tailings has been conducted and is discussed in section D.3.7, Off-Pile Contamination.

An area of contamination northeast of the Phillips/UNC tailings pile is readily apparent and extends nearly a mile to the east-northeast from the pile edge. The contamination due to windblown tailings versus that resulting from Section 27 mine windblown ore has been estimated by Bendix (BFEC, 1985b). The shape of the contour between areas "C" and "D" indicates that only in the immediate vicinity (500 to 1000 feet) of the mine workings does windblown ore dominate the contamination. This is to be expected due to the larger-than-tailings particle size of typical ore material.

D.3.7 OFF-PILE CONTAMINATION

The off-pile surface contamination data reflect the extent of windblown and waterborne contamination as well as contamination due to ore storage and mining operations. FBDU (1981) conducted off-pile surface contamination surveys, using delta measurements and, based on these surveys, determined a preliminary 5 pCi/g Ra-226 boundary (Figure D.3.4). The measurements were made using a lead shielded, unidirectional scintillometer. By taking the measurements with the unshielded end one inch above ground surface, and then placing a 0.5-inch shield over the unshielded surface and repeating the measurements, a difference is obtained. This difference, known as "delta," can be used to estimate the contamination at the point of measurement (FBDU, 1981). Based on the small amount of data obtained, the distance between sample traverses, and the lack of evidence of a good calibration, the FBDU boundary in Figure D.3.4 is considered only an approximation.

Limited surface soil sampling was also conducted at the site (ORNL, 1980). The results of the survey are shown in Table D.3.2. The samples indicate that extensive contamination exists in the ephemeral washes around the site. Because of the limited nature of the ORNL sampling program, all that can be assessed is that there are indications of contamination across and extending far beyond the designated site.

In order to obtain a more reliable estimate of the areal extent of the off-pile surface and subsurface contamination, a more extensive survey was conducted by Bendix (BFEC, 1985b). The sampling procedure used by BFEC allows an accurate determination of the extent of contamination off the pile.

Several methods were employed to determine Ra-226 activity. Soil samples and delta measurements were taken to aid in the characterization of the areal extent of the contamination to a depth of 24 inches. The extent of contamination below 24 inches was determined by borehole gamma-logging and analysis of split-barrel soil samples.

Soil samples and delta measurements were taken in an alternating manner. Initially, a zero-to-six-inch depth soil sample was collected, followed by a delta measurement at the six-inch depth. If the delta measurement detected a Ra-226 concentration in excess of 5 pCi/g, a second soil sample (six-to-twelve-inch) was collected, followed by a 12-inch delta measurement. This alternating sequence was repeated until either the delta measurement indicated a value less than 5 pCi/g or a depth of 24 inches was reached. All soil samples were analyzed using gamma-ray spectrometry for Ra-226 content. Several were also analyzed for Th-230 and natural uranium contents.

The extent of contamination below 24 inches was determined by interpretation of the results of 225 off-pile borehole gamma-logs. Log data were recorded in successively deeper six-inch intervals. In 41 of the borehole locations, split-barrel soil samples were also taken and analyzed by gamma-ray spectrometry.

The soil sample results were used to determine the areal extent and depth of Ra-226 concentrations exceeding 5 pCi/g (Figure D.3.5).

Because a portion of the contamination was thought to result from spillage of ore during uranium mining and transport activities, it was necessary to examine the Ra-226/U-238 ratio in a number of samples to determine whether the associated radioactivity was attributable to uranium ore or tailings. The Ra-226/U-238 ratio was determined for 19 samples known to be ore and six samples known to be composed of tailings. A Behrens-Fischer T-test and a Wilcoxon Two-Sample Rank Test were performed on the two sample populations; from these tests, it was determined that with a 99 percent degree of confidence the means of the two sample populations could be distinguished. A mean Ra-226/U-238 ratio of 2.28 was determined for the ore samples along with a standard deviation of 0.759. The mean Ra-226/U-238 ratio of the tailings samples was 8.31 with a standard deviation of 3.01. A mean Ra-226/U-238 ratio of 12.3 can be derived from Mountain States Research and Development borehole samples taken directly from the tailings pile (MSRD, 1982). Assuming that the ratios for ore and tailings are normally distributed, 95 percent confidence intervals for ore and tailings were 1.91-2.65 and 5.15-11.47, respectively. A conservative ratio of four was used as the cut-off value in discerning between a soil sample containing ore and one containing tailings. Soil contaminated with ore is not required to be cleaned up under the UMTRA Project.

Figure D.3.5 also indicates the off-pile areas contaminated below 0.5 foot. The average depth of contamination in the twelve areas drawn ranges from one foot to 10.5 feet. The average depth of contamination in each area identified in Figure D.3.5 was estimated by determining the depth to the 5 pCi/g concentration at each measurement location and averaging the depths. In most areas, the depth to the 5 pCi/g concentration was six inches below the 15 pCi/g interface. Furthermore, it was felt that if backfilling of an area would be required, this decision was best made during the remedial action.

Note that the depths of contamination shown in Figure D.3.5 are average depths. It is not intended that these entire areas be excavated uniformly to this average depth. These average depths were used for preliminary volume estimates only. The depth of contamination to the 5 and 15 pCi/g concentration at each measurement location is listed in Table D.3.3 by location identification number. Plate 1 is a map showing the relative position of each measurement location and the depth to the 5 pCi/g Ra-226 concentration. The actual depth of excavation at any particular point must be determined by excavation control measurements during remedial action.

Adjacent to the eastern and northern edge of the pile are the mill yard, ore storage area, and Ann Lee Mine. The average depth of contamination in this area is two feet and ranges from zero to five feet. Refer to Plate 1 to determine the depth to the 5 pCi/g concentration at a given measurement location.

East of the drainage canal is the leach pad and the protore storage pile. The leach pad was an experimental facility used to process low-grade protore extracted from the Section 27 mine. The pile east and south of the leach pad is a stockpile of protore. The depth of contamination in the 1.10-acre leach pad area is based on the average of two borehole measurement locations. One hole had a total contaminated depth of 5.5 feet; the other hole indicated contamination to a depth of 15.5 feet. The protore storage pile had an average depth of 5.5 feet. This pile is surrounded by 13.13 acres contaminated to an average depth of 3.5 feet.

The topography of the protore storage pile is irregular. It was estimated that ridges extending an average of 4.2 feet above the local ground surface cover one-third of the pile area. Six boreholes

D.9 METEOROLOGICAL DATA

D.9.1 PURPOSE

Meteorological data are provided to:

- o Estimate the length of the construction season.
- o Plan construction dust control.
- o Plan construction runoff control.
- o Design long-term erosion control.
- o Determine long-term moisture content of cover materials.
- o Determine any extraordinary protection required for personnel or equipment.

D.9.2 WEATHER PATTERNS

The climate of the Ambrosia Lake area is characterized by low precipitation, abundant sunshine, low relative humidity, and moderate temperatures with large diurnal and annual ranges. The regional climate is classified as semi-arid and continental (QMC, 1981).

D.9.3 WIND

The topography in the area suggests a wind regime dominated by two major influences: nighttime drainage of cold air from the high mesas, and channeling of synoptic winds through the northwest-southeast oriented valley (QMC, 1981).

The wind data from a meteorological station operated by the New Mexico Environmental Improvement Division (NMEID) 0.25 mile north of the tailings pile are presented in Table D.9.1 and Figure D.9.1. The predominant wind directions observed were westerly and north-northwesterly.

Wind data from the combined National Weather Service Stations at Acomita and Grants, New Mexico, are considered representative of regional wind conditions. Wind data from this station are presented in Table D.9.2. At the Acomita-Grants weather station, 17 miles southeast of the tailings site, the annual average wind speed is 9.3 miles per hour (all directions); the most frequent wind directions are from the west (19.6 percent) and northwest (13.1 percent). Calm conditions occur 6.6 percent of the time (FBDU, 1983).

D.9.4 TEMPERATURE

The Ambrosia Lake area exhibits a large diurnal range in temperature, which is conducive to nighttime inversion formations. Ten and one-half months of measurements at the NMEID monitoring site show a mean daily minimum of 40.9°F, and a mean daily maximum of 65.2°F. The mean daily average of 53.5°F agrees reasonably well with the long-term (1962-1974) average of 49.2°F measured at the Floyd Lee Ranch near San Mateo, New Mexico, 13 miles southeast of the tailings site (QMC, 1981).

Gulf Mineral Resources Company has established several meteorological monitoring stations in the Mt. Taylor area. Temperature data from station No. 1 at 7280 feet near San Mateo, New Mexico, are given in Table D.9.3 for a one-year period between February, 1976, and January, 1977 (QMC, 1981). Temperatures at this station are expected to be somewhat lower than those at the tailings site due to the difference in elevation between the two locations.

D.9.5 PRECIPITATION

Most of the precipitation in the project area occurs during the late summer thunderstorm season, although there is considerable monthly and annual variation in total rainfall. Table D.9.4 presents long-term precipitation measurements made at San Mateo (Floyd Lee Ranch) and three other regional stations. The long-term annual average for San Mateo was 8.83 inches with a maximum of 13.55 inches in 1956. August was the wettest month with an average of 2.13 inches, and a maximum of 4.38 inches in 1948. Most of the winter precipitation in this area falls as snow (QMC, 1981).

D.9.6 FROST

Freezing and thawing of the surface occurs frequently from December through March. The average annual frost-free period is 120 days (NOAA, 1979). The average maximum frost penetration in soils in the Ambrosia Lake area based on a 40-year period of record (1944-1984) is 24 inches (Losito, 1985).

D.9.7 EVAPORATION

The mean annual lake evaporation in the area is 54 inches. Seventy-two percent of the annual evaporation occurs from May through October (NOAA, 1979).

D.8 GROUNDWATER HYDROLOGY

D.8.1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has established health and environmental protection regulations to correct and prevent groundwater contamination resulting from processing activities at inactive uranium processing sites (40 CFR 192). According to the Uranium Mill Tailings Radiation Control Act (UMTRCA), the U.S. Department of Energy (DOE) is responsible for assessing the processing sites. The DOE has determined this assessment shall include (DOE, 1988):

- o Definition of hydrogeologic characteristics of the environment, including hydrostratigraphy, aquifer parameters, areas of aquifer recharge and discharge, potentiometric surface, and groundwater velocity.

- o Comparison of existing water quality with background water quality, and the maximum concentration limits (MCLs) of the proposed EPA groundwater protection standards.

- o Definition of physical and chemical characteristics of the contaminant source, including concentration and leachability of the source in relation to migration in groundwater and hydraulically connected surface water.

- o Description of local water use including availability, current and future use and value, and alternative supplies.

- o Evaluation of the compliance of the remedial action with the EPA groundwater protection standards.

On January 5, 1983, the EPA promulgated final standards for the disposal and cleanup of the inactive uranium processing sites under the UMTRCA (48 FR 590). On September 3, 1985, the groundwater provisions of the regulations (40 CFR 192.20(a)(2)-(3)) were remanded to the EPA by the U.S. Tenth Circuit Court of Appeals. On September 24, 1987, the EPA issued proposed groundwater regulations to replace those set aside (52 FR 36000).

The DOE characterized groundwater quality at the Ambrosia Lake tailings site and compared it with the MCLs of the proposed EPA groundwater standards for remedial action at inactive uranium processing sites. The DOE does not anticipate that any substantial changes to the remedial action design will be required to comply with the final EPA groundwater standards. When the final EPA groundwater protection standards are issued, the DOE will fully determine the need for institutional controls, aquifer restoration, or other controls as part of a separate decision-making process under the National Environmental Policy Act.

Summary

To comply with the proposed EPA groundwater protection standards for remedial action at inactive uranium mill tailings sites (40 CFR Part 192), the DOE has characterized the hydrogeology, groundwater quality, and water resources at the Ambrosia Lake site in New Mexico. This summary is followed by a detailed discussion of the site characterization.

- The Ambrosia Lake tailings site is underlain by alluvium which grades into weathered Mancos Shale on the eastern side of the site. The alluvium/weathered Mancos Shale are hydraulically interconnected and behave as a single hydrologic unit. The Tres Hermanos-C Sandstone of the lower Mancos Shale subcrops into the alluvium beneath the western side of the tailings site. Other hydrostratigraphic units beneath the site which may be water-bearing include (in descending order) the Tres Hermanos-B and -A Sandstones of the lower Mancos Shale, the Dakota Formation, and the Westwater Canyon Member of the Morrison Formation.

- The condition of saturation in the alluvium/weathered Mancos Shale at the site exists due to the uranium mining activities in the area. Seepage from an unlined mill make up process water pond, discharge of mine water from the Ann Lee Mine, and seepage from the tailings have artificially recharged groundwater in the alluvium and weathered Mancos Shale. Groundwater in the area of saturation in the alluvium/weathered Mancos Shale north of the pile flows to the southwest under the tailings along the southwesterly sloping contact of the Mancos Shale under a hydraulic gradient averaging 0.025 foot per foot. The average hydraulic conductivity in the alluvium/weathered Mancos Shale is 3.48×10^{-4} centimeter per second (cm/s) and the average linear groundwater velocity is 6.69×10^{-5} cm/s.

- The alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone are incapable of producing more than 150 gallons per day, which classifies the groundwater contained in these units as limited use (Class III) groundwater. The existing level of saturation in the alluvium/weathered Mancos Shale will probably not be sustained after remedial actions are completed. Groundwater within the Tres Hermanos-C Sandstone is recharged mostly from seepage from the alluvium in the subcrop area. The extent of recharge from the alluvium will diminish after remedial action.

- The Tres Hermanos-C Sandstone is only basally saturated, receiving most of its recharge from the overlying alluvium/weathered Mancos Shale where it subcrops on the western side of the pile. Groundwater within the Tres Hermanos-C Sandstone flows to the northeast in the direction of regional dip under a hydraulic gradient averaging 0.025 ft/ft. The average hydraulic

conductivity in the Tres Hermanos-C Sandstone is 2.67 x 10^{-4} cm/s and the average linear groundwater velocity is 1.37 x 10^{-4} cm/s.

- Groundwater within the Westwater Canyon Member of the Morrison Formation flows to the northeast in the direction of regional dip under a hydraulic gradient averaging 0.026 ft/ft. The average hydraulic conductivity in the Westwater Canyon Member is 4.31 x 10^{-4} cm/s and the average linear groundwater velocity is 1.14 x 10^{-4} cm/s.

- Because there was originally no saturation in the alluvium, no pre-operational water quality data is available. It is only possible to establish existing water quality as background for the isolated pocket of saturation in the alluvium and weathered Mancos Shale.

- Maximum observed concentrations of chromium, molybdenum, nitrate, lead, selenium, silver, uranium, and activities of radium 226 and 228 and gross alpha in pore fluids in the tailings and unsaturated alluvium beneath the tailings exceed the proposed MCLs.

- Maximum observed concentrations of chromium, molybdenum, nitrate, lead, selenium, silver, uranium, and activities of radium 226 and 228 and gross alpha in groundwater in the alluvium/weathered Mancos Shale exceed the proposed MCLs. Maximum observed concentrations of cadmium, chromium, molybdenum, nitrate, selenium, silver, uranium, and activities of radium 226 and 228 and gross alpha in groundwater in the Tres Hermanos-C Sandstone Member exceed the proposed MCLs.

- Maximum observed concentrations of cadmium, chromium, lead, molybdenum, selenium, silver, uranium, and activities of radium 226 and radium 228 in groundwater in the Westwater Canyon Member of the Morrison Formation exceed the proposed MCLs.

- Geochemical simulation of mixing tailings pore fluids with mill make-up water suggests that groundwater in the alluvium/weathered Mancos Shale is derived largely from these two sources. Concentrations of nitrate, a conservative species, are relatively the same in groundwater in the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone suggesting much of the groundwater in the Tres Hermanos-C Sandstone is derived from seepage from the alluvium/weathered Mancos Shale.

- A comparison of concentrations of hazardous constituents in the Tres Hermanos-C Sandstone with those in the Westwater Canyon Member of the Morrison Formation indicates that seepage down mine shafts and vent holes will not influence water quality in the Westwater Canyon Member. Concentrations of most hazardous constituents in the Tres Hermanos-C Sandstone are lower than those in the Westwater Canyon Member and the relative rate of groundwater underflow in the Westwater Canyon Member compared to the Tres Hermanos-C Sandstone assures that no water quality impacts will occur in the Westwater Canyon Member.

D.8.2 GROUNDWATER INVESTIGATIONS

Regional hydrogeologic investigations have been conducted in the southern portion of the San Juan Basin in McKinley County, which includes the Ambrosia Lake uranium mining district, by the state of New Mexico (Brod and Stone, 1981; Cooper and John, 1968). Extensive uranium exploration, mining, and milling activities in the Ambrosia Lake area from the 1950's through the 1980's have resulted in publication of economic mineral investigations by Federal and state government agencies, reports by mining companies conducting operations in the district, and reports on water resources and water quality resulting from these activities.

Preliminary site-specific investigations conducted at the Ambrosia Lake uranium mill tailings site include an engineering assessment by Ford, Bacon & Davis Utah Inc. (FBDU, 1981), an economic evaluation of the uranium mill tailings by Mountain States Research and Development (MSRD, 1982), and a preliminary environmental assessment by the DOE (DOE, 1983).

Additional hydrogeologic field data were collected by the DOE during 1985 and 1989 to further characterize the lithology, groundwater elevations and hydraulic gradients, aquifer properties, and groundwater quality at the Ambrosia Lake site. In 1985, the DOE installed 26 four-inch polyvinyl chloride (PVC) monitor wells (773 through 799) at the site (Figure D.8.1 and Table D.8.1). In 1989, the DOE installed another eight, four-inch PVC monitor wells (674 through 681) at the site. Details of monitor well construction and installation are available for review in the Uranium Mill Tailings Remedial Action (UMTRA) Project Office, Albuquerque, New Mexico. Of the 34 monitor wells, 15 are currently being sampled for water quality analyses, 13 are dry, four are not being sampled because of high pH values resulting from grout contamination during installation, and two have been sealed to facilitate the remedial action program. The monitor wells have been screened in several hydrostratigraphic units, including the alluvium/weathered Mancos Shale, the Tres Hermanos-C, -B and -A Sandstone units, and the Dakota Sandstone. Of the 15 wells currently being sampled, four are in the alluvium, seven are in the Tres Hermanos-C Sandstone, and two are in the Tres Hermanos-B Sandstone, and one each in the Tres Hermanos-A and Dakota Sandstones. To characterize tailings fluids, two lysimeters and nine well points were installed in the tailings material (Figure D.8.2 and Table D.8.2).

Groundwater elevations were measured in monitor wells during October 1985, May 1986, April and July 1988, and February 1989 to construct potentiometric surface maps to determine the directions of groundwater flow. Slug tests were performed in monitor wells to measure hydraulic conductivities of lithologic units under the site. A pumping test was performed in a monitor well to determine the transmissivity, storativity, and sustainable yield of the alluvium/weathered Mancos Shale. Water samples were collected from monitor wells during October 1985, May 1986, April and July 1988, and February 1989 to determine background water quality, and the degree and extent of contamination caused by the uranium mill tailings at the site. All field and laboratory procedures and calculations were performed in accordance with the DOE Technical Approach Document (DOE, 1989).

D.8.3 HYDROSTRATIGRAPHY

The Ambrosia ~~Lake~~ tailings site is underlain by alluvium (Quaternary) which grades into weathered Mancos Shale (Cretaceous) on the eastern side of the site. The Tres Hermanos-C Sandstone of the lower Mancos Shale subcrops into the alluvium beneath the western side of the tailings site. Other hydrostratigraphic units beneath the site which may be water-bearing include (in descending order) the Tres Hermanos-B and -A Sandstones of the lower Mancos Shale, the Dakota Formation (Cretaceous), and the Westwater Canyon Member of the Morrison Formation (Jurassic). Hydrostratigraphic units below the Westwater Canyon Member will not be impacted by tailings seepage because there is an upward hydraulic gradient into the Westwater Canyon Member, and the underlying units are separated by more than 150 feet of shale, siltstone, and sandstone of the Recapture Member of the Morrison Formation, which was not disturbed during uranium mining.

The alluvium at the site generally consists of very fine-grained sand and clay with occasional basal gravel layers. The alluvium was deposited on the southwestward sloping bedrock surface, and ranges in thickness from several feet on the east side of the tailings to almost 60 feet on the west side of the southwest corner of the tailings (Figure D.8.3).

Bedrock at the site dips several degrees to the northeast (Figures D.8.4 through D.8.8). Because the topography slopes to the southwest, progressively older bedrock formations subcrop beneath the alluvium in this direction. The Mancos Shale subcrops in the alluvium under the eastern side of the tailings, and the Tres Hermanos-C Sandstone subcrops under the alluvium on the western side of the tailings (Figures D.8.4 through D.8.8). The Tres Hermanos-C Sandstone consists of an upper (Tres Hermanos-C1) and lower (Tres Hermanos-C2) member separated by a 10- to 15-foot thick interbed of shale near the top of the unit. The Tres Hermanos-C Sandstone unit has an average thickness of 60 feet and grades into the Mancos Shale near the bottom. Approximately 50 feet of Mancos Shale separates the Tres Hermanos-C Sandstone from the underlying Tres Hermanos-B Sandstone. Generally, no water quality impacts from tailings seepage have occurred in deeper formations below the Tres Hermanos-C Sandstone because they subcrop to the southwest of the tailings and are separated from the Tres Hermanos-C Sandstone by the low hydraulic conductivity Mancos Shale. However, some groundwater affected by tailings seepage may discharge down mine shafts and vent holes to the Westwater Canyon Member in the site vicinity.

The Westwater Canyon Member of the Morrison Formation is approximately 200 feet thick in the area and consists of fine- to coarse-grained arkosic sandstone typical of fluvial deposits. Uranium ore within the Westwater Canyon Member has been extensively mined in the Ambrosia Lake mining district.

D.8.4 HYDRAULIC CHARACTERISTICS

Unconfined groundwater occurs in the alluvium/weathered Mancos Shale. Depths to groundwater range from 15 to 45 feet. A water table map for the alluvium/weathered Mancos Shale is presented in Figure D.8.9. The alluvium/weathered Mancos Shale is not continuously saturated in the vicinity of the tailings pile. The maximum observed thickness of saturation in the alluvium/weathered Mancos Shale is no more than 15 feet and occurs south of the western corner of the tailings pile (monitor well 675). The alluvium has been found to be saturated only along the northeastern portion of the tailings pile, but the alluvium remains dry to the south and west of the tailings. Hydrographs of wells screened in the alluvium/weathered Mancos Shale located along the northeast corner of the tailings pile indicate groundwater levels have dropped approximately 1.5 feet between the period of October 1985 to February 1989 (Figure D.8.10 and Table D.8.3). Groundwater levels have remained relatively constant in wells screened in the Tres Hermanos-C Sandstone over the same period of time. Groundwater elevation data from monitor wells completed through the tailings into the alluvium and weathered Mancos suggest that there may be some extent of saturation below the tailings. However, wells completed through the tailings were not used to prepare the water table map because the integrity of well seals in tailings could not be determined.

Groundwater within the alluvium/weathered Mancos Shale is naturally recharged by flows from arroyos off Roman Hill to the northeast of the site. Some basal saturation may occur where the alluvium is underlain by the relatively low-hydraulic conductivity unweathered Mancos Shale. Seepage from the unlined mill process (make-up) water pond, discharge of mine water from dewatering the Ann Lee Mine, and seepage from the tailings have artificially recharged groundwater in the alluvium and weathered Mancos Shale at the site (Figure D.8.6). Cravens and Hammock (1958) report "the valley fill (alluvium) does not contain much water north of the McKinley County line. All water in the alluvium north of the McKinley County line is either seepage from waste ponds at the Kerr McGee (Quivira) and Phillips (Ambrosia Lake tailings site) mills or mine water, which is pumped to the surface from the Westwater Canyon Member of the Morrison Formation."

Groundwater in the area of saturation in the alluvium/weathered Mancos Shale north of the pile flows to the southwest under the tailings along the southwestward sloping contact of the Mancos Shale under a hydraulic gradient averaging 0.025 foot per foot (ft/ft)

(Figure D.8.9). Groundwater commingles with tailings seepage as it flows under the pile and recharges the Tres Hermanos-C Sandstone in its subcrop area in the western side of the tailings (Figure D.8.6). Monitor wells to the southwest of the tailings are dry because the Tres Hermanos-C Sandstone accepts the flow in the alluvium/weathered Mancos Shale. Although some saturation in the alluvium is evident several thousand feet southwest of the site, this groundwater is associated with the discharge of mine dewatering in the Arroyo del Puerto, which is topographically much lower and not hydraulically connected to the alluvium at the Ambrosia Lake site.

Groundwater within both the upper and lower Tres Hermanos-C Sandstone beds flow to the northeast in the direction of regional dip under a hydraulic gradient averaging 0.026 ft/ft for the upper (Tres Hermanos-C1) and the lower (Tres Hermanos-C2) member (Figures D.8.5, D.8.6, D.8.11, and D.8.12). The Tres Hermanos-C Sandstone is unconfined in the vicinity of the tailings and groundwater elevations from monitor wells completed in both the upper and lower sandstone beds (which are separated by 10 to 15 feet of shale) suggest that there is basal saturation in each unit. The Tres Hermanos-C Sandstone may have originally been saturated in the premining days, but was depressurized by seepage down mine shafts and vent holes in the vicinity. Existing basal saturation is probably sustained by recharge from the alluvium in the subcrop area of the Tres Hermanos-C Sandstone.

The Tres Hermanos-B Sandstone is separated from the Tres Hermanos-C Sandstone by 50 feet of contiguous Mancos Shale. This shale is of sufficiently low-hydraulic conductivity to prevent the vertical migration of contaminants, even though there are vertically downward hydraulic gradients. Groundwater within Tres Hermanos-B Sandstone beds flows to the northeast in the direction of regional dip under a hydraulic gradient averaging 0.04 ft/ft (Figures D.8.5, D.8.6, and D.8.13). Monitor well 789, completed in the top of the Tres Hermanos-B Sandstone is dry, which indicates that there may be only basal saturation in the Tres Hermanos-B as seepage down mine shafts and vent holes has caused depressurization. Flow down mine shafts and vent holes could not potentially contaminate the Tres Hermanos-B Sandstone or any other water-bearing formations above the Westwater Canyon Member because the mine shafts and vent holes are points of groundwater discharge. Furthermore, the Tres Hermanos-B subcrops in the alluvium to the west of the site and contamination in the alluvium from the site could not potentially recharge the Tres Hermanos-B Sandstone.

Groundwater in the Westwater Canyon Member flowed downdip to the northeast into the San Juan Basin during premining days (Figure D.8.14). Development of the ore body necessitated dewatering of the Westwater Canyon Member. The potentiometric surface has been modeled (Lyford et al., 1978) and the potentiometric surface of the Westwater Canyon Member in the Ambrosia Lake area represents a potentiometric trough depressurized by several hundred feet (Figure D.8.15). Groundwater will continue to flow towards this trough for approximately the next 100 years as the Westwater Canyon Member starts to repressurize. Flow in the site area is probably downdip towards the Ann Lee Mine or towards the potentimetric depression to the southeast (Figure D.8.16).

Several falling head slug displacement tests were conducted in the monitor wells at the Ambrosia Lake site to measure the hydraulic conductivities of the lithologic units under the site. Methods used to analyze the slug test data and the calculated hydraulic conductivities are summarized in Table D.8.4. Calculations are on file at the Albuquerque Operations UMTRA Project office.

An aquifer pumping test was performed in the alluvium/weathered Mancos Shale in well 675, located 200 hundred feet south of the Ambrosia Lake tailings pile. The modified Theis method (Jacob straight-line method) was used to analyse the pumping test data, yielding transmissivities ranging from 13 to 18 gallons per day per square foot (gpd/ft^2) and a storage coefficient of 0.001. The saturated thickness of the alluvium/weathered Mancos Shale at this location is 15 feet, yielding hydraulic conductivities ranging from 4.1 x 10^{-5} centimeters per second (cm/s) and 5.7 x 10^{-5} cm/s. The discharge rate during the pumping test was 0.35 gallons per minute (500 gallons per day) which could only be sustained for 12 hours before the pump broke suction when the drawdown exceeded 13 feet. Slug test data obtained from wells screened in the alluvium/weathered Mancos Shale yielded hydraulic conductivities comparable to the pumping test with a range of 1.9 x 10^{-5} cm/s to 1.1 x 10^{-3} cm/s and an average hydraulic conductivity of 1.4 x 10^{-4} cm/s (Table D.8.4).

Horizontal hydraulic conductivities measured from slug tests in monitor wells in the Tres Hermanos-C Sandstone ranged from 1.1 x 10^{-5} cm/s to 1.2 x 10^{-3} cm/s and averaged 2.5 x 10^{-4} cm/s. Monitor wells in the subcrop area of the Tres Hermanos-C Sandstone generally have higher hydraulic conductivities than the alluvium/weathered Mancos Shale or the portions of the Tres Hermanos-C Sandstone that are overlain by Mancos Shale. No pumping tests have been conducted by other investigators in the Tres Hermanos-C Sandstone because the sandstone is either not present or is unsaturated to the southwest of the Ambrosia Lake site.

Other investigators have also measured aquifer parameters in the Ambrosia Lake region. Hydraulic conductivities reported by these investigators for the alluvium, Tres Hermanos-B Sandstone and the Mancos Shale are presented in Table D.8.5.

Hydraulic conductivities of 1.0 x 10^{-3} cm/s to 5.0 x 10^{-3} cm/s were measured in slug tests in the alluvium at the Ambrosia Lake site (Thomson and Heggen, 1981). Two aquifer pumping tests, performed in wells AW-1 and AW-2 (shown in Figure D.8.17) in the central channel of alluvium in the Arroyo del Puerto in the vicinity of Quivera Mining Company operations, yielded hydraulic conductivities of 2 x 10^{-4} cm/s and 5 x 10^{-4} cm/s and a storage coefficient of 2 x 10^{-5} (Garus, 1980). These pumping tests were conducted in the thickest portion of the alluvium where sediments are substantially coarser than at the Ambrosia Lake site.

Hydraulic conductivities of the Mancos Shale have been measured by several investigators in the Ambrosia Lake region. Weathered Mancos

Shale may range from 1.4 x 10^{-6} to 1.4 x 10^{-7} cm/s in horizontal hydraulic conductivity (Brod and Stone, 1981). However, a hydraulic conductivity of 4.3 x 10^{-8} cm/s was measured in undisturbed Mancos Shale and is probably representative of the vertical hydraulic conductivity of the Mancos Shale aquitard that occurs between the Tres Hermanos-C and the Tres Hermanos-B Sandstones (Thomson and Heggen, 1981).

The Tres Hermanos-C, -B, and -A Sandstones encountered at the Ambrosia Lake site are fine-grained (silt and very fine-grained sandstone) and are not easily distinguishable from the Mancos Shale. During drilling, the contacts between each Tres Hermanos Sandstone Member and the Mancos Shale often occurred as a subtle gradational lithologic change rather than a distinct and abrupt lithologic change with contact locations that could be discerned only on the basis of minor lithologic changes observed from geophysical logs. The gradual nature in litholigic changes between the Tres Hermanos sandstones and the Mancos Shale are reflected by the absence of sharp permeability contrasts between the Tres Hermanos Sandstones and the Mancos Shale. In particular, the hydraulic conductivities of the Tres Hermanos-B and -A Sandstones were too low to be quantified by slug tests. The Tres Hermanos-C had higher groundwater yields than the -A and -B Sandstones mainly due to the recharge the Tres Hermanos-C Sandstone receives from the overlying alluvium/weathered Mancos Shale.

In situ single packer permeability tests conducted in the Tres Hermanos-B Sandstone in the vicinity of the Quivira Mining Company operations measured composite horizontal and vertical hydraulic conductivities that ranged from 1 x 10^{-3} to 1 x 10^{-4} cm/s.

Transmissivities for the Westwater Canyon Member were reported by Kelly et al. (1980) to range from 100 to 300 ft^2/day. If the Westwater Canyon Member is approximately 200 feet thick, this would yield a hydraulic conductivity ranging from 7.74 x 10^{-7} to 2.32 x 10^{-6} cm/s.

Darcy's Law was used to calculate average linear groundwater velocities for the alluvium/weathered Mancos Shale, and the Tres Hermanos-C Sandstone. Using the hydraulic conductivities and hydraulic gradients of the alluvium/weathered Mancos Shale, and the Tres Hermanos-C Sandstone, and assuming effective porosities of 13 and five percent, average linear groundwater velocities are 365 and 438 ft/yr, respectively (Table D.8.6).

The Theis equation (Freeze and Cherry, 1979) was used to compute drawdown in a hypothetical well completed in the alluvium/weathered Mancos Shale to determine if the well could sustain a yield of 150 gallons per day for an extended period of time. A yield of less than 150 gallons per day classifies the groundwater in the alluvium/weathered Mancos Shale as Class III by the criterion of limited use. The values for transmissivity and storage coefficient were obtained from an analysis of data collected during the pumping test performed on monitor well 675. Monitor well 675 was installed to a depth of 35 feet, penetrating the entire thickness of the alluvium/weathered Mancos Shale, which has a saturated thickness of approximately 15 feet at that location. The saturated thickness for the alluvium/weathered Mancos Shale at the site is not constant or continuous and can vary from being unsaturated to being saturated to a thickness of 15 feet. Monitor well 675 was chosen for the pumping test because it has the largest saturated thickness of the monitor wells installed in the alluvium/weathered Mancos Shale and probably produces the maximum amount of groundwater that can be obtained from the alluvium/weathered Mancos Shale at the site. Typically, as a rule of thumb, the maximum allowable drawdown for a well screened in water-table conditions is two-thirds the saturated thickness of the aquifer. Assuming a maximum saturated thickness of 15 feet, the maximum allowable drawdown is 2/3 x 15 feet = 10 feet. Assuming an average transmissivity of 15 gallons per day per foot, a storage coefficient of 0.001, and 10 feet as the maximum amount of available drawdown for the alluvium/weathered Mancos Shale aquifer, a constant discharge of 150 gallons per day cannot be sustained for more than a day (Table D.8.7). The discharge from monitor well 675 during the pump test had a total dissolved solids (TDS) concentration of 7200 milligrams per liter (mg/l). The limited extent of saturation within the alluvium/weathered Mancos Shale is a boundary condition that was not factored into the computation and provides additional conservatism to the computation of the long-term sustained yield.

D.8.5 BACKGROUND GROUNDWATER QUALITY

Background groundwater quality in the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone at the Ambrosia Lake site is considered existing water quality because mining and milling activities have created the conditions of saturation (Bostick, 1985). Groundwater within the alluvium/weathered Mancos Shale has been demonstrated through geochemical modeling to be derived from reinfiltration of mine dewatering discharge or tailings seepage (Section D.8.8).

Because there was originally no measurable water in the alluvium, preoperational water quality data are not available for the Ambrosia Lake site. It is only possible to establish existing water quality as background for the isolated pocket of saturation within the alluvium/weathered Mancos Shale. Furthermore, the existing level of saturation in the alluvium/weathered Mancos Shale will probably not be sustained after remedial actions are completed. The concept of background water quality applies only to a sustainable aquifer with upgradient groundwater flow and the alluvium/weathered Mancos Shale are not aquifers. Existing water quality is therefore characterized in Section D.8.7, Extent of Existing Contamination.

Groundwater within the Tres Hermanos-C Sandstone at the Ambrosia Lake site is recharged primarily from seepage from the alluvium in the subcrop area. The extent of recharge from the alluvium will diminish after remedial action. Existing levels of saturation within the Tres Hermanos-C Sandstone may decrease as groundwater continues to drain into mine shafts and vent holes. However, the Tres Hermanos-C Sandstone may eventually repressurize, if the current trend of reducing mine dewatering persists. Some repressurization will probably occur by groundwater flow through mine shafts and vent holes completed in the Westwater Canyon Member up through the hydrostratigraphic section. Because levels of saturation are variable, there is no upgradient groundwater underflow and sources of recharge may change with time, existing water quality in the Tres Hermanos-C Sandstone must also be defined as background (Section D.8.7).

Present background groundwater quality of the Westwater Canyon Member has been identified in the Ambrosia Lake region by samples from mine water discharge (Table D.8.8). Water quality in the Westwater Canyon Member has changed as a result of commingling of seepage from overlying formations down mine shafts and vent holes. Kelly (1980) found groundwater from the Westwater Canyon Member to be a sodium bicarbonate type (Figure D.8.18). The percentage of sulfate in mine water discharges from the Ann Lee Mine became higher over the period from 1963 to 1979, which may reflect the influence of seepage from the overlying Dakota Formation and tailings seepage within the Tres Hermanos-C Sandstone flowing down mine shafts and vent holes into the Westwater Canyon Member. Concentrations of cadmium, chromium, lead, molybdenum, selenium, silver, and uranium, and activities of radium-226 and -228 exceed the EPA MCLs in the Westwater Canyon Member. It is necessary to determine background water quality for the Westwater Canyon Member, because most of the existing saturation in the Tres Hermanos-C Sandstone will drain into the Westwater Canyon Member through mine shafts and vent holes. The effects of the proposed remedial action on water quality in the Westwater Canyon Member, are discussed in Section D.8.8.4.

D.8.6 TAILINGS CHARACTERIZATION

Uranium ore was extracted using an alkaline leach process from 1958 to 1963 at the Ambrosia Lake site (Figure D.8.19). The main chemicals added in the mill process were sodium carbonate (Na_2CO_3) and sodium hydroxide ($NaOH$) (caustic). In the precipitation process, sulfuric acid and ammonia are converted to a sodium salt. The sodium salt, along with other chemical constituents (Table D.8.9), was disposed of in the tailings pond. A complete chemical analysis of this effluent is not available, but chemical compositions of alkaline-leach effluent are found in the literature (Table D.8.10). The constituents of most concern for groundwater contamination, due to their high concentrations or potential health impacts, are selenium, molybdenum, nitrate, sodium, radium-226 and -228, sulfate, and uranium.

To characterize tailings fluids, two lysimeters and nine well points were installed in the tailings material (Figure D.8.2 and Table D.8.2). Major ions used to trace the extent of pond seepage migration in the groundwater are sulfate and sodium. A sulfate salt was the predominant component of the effluent discharged to the pile. Sulfate is a conservative species that travels relatively unimpeded in the groundwater flow system. Sodium is not a conservative tracer, since it is subject to ion exchange reactions. However, the large amount of soluble sodium discharged to the pile makes it a prime indicator for tailings pile seepage. Molybdenum, also not a conservative tracer but present in higher concentrations, was used as an additional indicator for tailings pile seepage.

Concentrations of sulfate, sodium, and molydenum in the tailings pore water (lysimeter 759) are shown in Figure D.8.20. Lysimeter 759 recovered pore water having sulfate, sodium, and molydenum concentrations of 11,000, 9880, and 247 mg/l, respectively. Tailings water from well points had concentrations of sulfate ranging from 5416 to 7890 mg/l, sodium ranging from 4190 to 6620 mg/l, and molybdenum ranging from 95.9 to 250 mg/l. These values are consistent with the chemical composition of alkaline leach mill effluent given in Tables D.8.9 and D.8.10.

A list of well points and lysimeters installed in the tailings where hazardous constituents with concentrations that exceed EPA MCLs or laboratory method detection limits were measured is given in Table D.8.11. The following constituents exceed the proposed EPA MCLs for most samples: molybdenum, radium-226 and -228, selenium, and uranium. Chromium and nitrate MCLs were exceeded in a small number of samples.

Lysimeter 757 was installed in the unsaturated alluvium/weathered Mancos Shale, beneath the tailings pile, and above the perched water table. The analyses of two pore water samples collected from 757 are listed in Table D.8.21. Concentrations of sulfate ranged from 7640 to 8010 mg/l, sodium ranged from 4790 to 6090 mg/l, and molybdenum concentrations ranged from 155 to 158 mg/l. These concentrations are within the range measured in the tailings pore water. This is to be expected as no mixing has taken place with the underlying perched water or groundwater.

Hazardous constituents analyzed in water samples collected from lysimeter 757 that exceed EPA MCLs are listed in Table D.8.11 and include molybdenum, nitrate, selenium, and uranium. Antimony, cobalt, copper, cyanide, fluoride, nickel, tin, vanadium and zinc are hazardous constituents without MCLs, but were present in tailings pore fluid at concentrations above laboratory method detection limits (Table D.8.16).

Tailings pore water was collected from lysimeter 751 for analysis of Appendix I organic constituents. Methyl ethyl ketone was the only Appendix I organic constituent detected, but at a concentration that was below the laboratory method detection limit. The maximum observed concentrations of Appendix I inorganic constituents for the tailings pore water are shown in Table D.8.11.

D.8.7 EXTENT OF EXISTING CONTAMINATION

Water samples were collected from monitor wells at the Ambrosia Lake site and analyzed to determine the quality of groundwater in the alluvium/weathered Mancos Shale and in the Tres Hermanos-C and -B Sandstones to define the extent of the groundwater contamination caused by seepage of leachate from the tailings pile and mine water discharge (Tables D.8.12 through D.8.20). Contaminants in groundwater related to the tailings pile and mine water discharge are present in the saturated zones of the alluvium/weathered Mancos Shale and in the Tres Hermanos-C Sandstone.

Alluvium and weathered Mancos Shale

Prior to the uranium mill activities, the alluvium/weathered Mancos Shale was unsaturated; therefore, background water quality is the existing groundwater quality (see Section D.8.5, Background Water Quality). Concentrations of chromium, molydenum, nitrate, lead, selenium, silver, and uranium, and activities of radium-226 and -228 and gross alpha in groundwater in the alluvium/weathered Mancos Shale exceed the proposed EPA MCLs (Table D.8.12). The sulfate anion is used as an indicator of the extent of tailings-related recharge in the alluvium/weathered Mancos Shale (Figure D.8.21). Monitor wells are probably influenced by tailings seepage as indicated by high sulfate concentrations in 674, 675, 792, and 793. Concentration distributions for molybdenum and uranium are shown in Figures D.8.22 and D.8.23 for the February 1989 sampling round.

No Appendix I organic constituents were detected in groundwater samples collected from monitor well 793, located along the northeast corner of the tailings pile. The maximum observed concentrations for Appendix I inorganic constituents in groundwater samples collected from the alluvium/weathered Mancos Shale are shown in Table D.8.17.

Tres Hermanos-C1 and -C2 Sandstone Members

The groundwater quality of the Tres Hermanos-C1 and C2 Sandstones are reported separately because wells screened in the two different units indicate different levels of contamination. Maximum observed concentrations of cadmium, chromium, molydenum, nitrate, selenium, silver, and uranium, and activities of radium-226 and -228 and gross alpha in groundwater in the Tres Hermanos-C1 Sandstone Member exceed the EPA MCLs (Table D.8.13). Maximum observed concentrations of chromium, molybdenum, selenium, silver, uranium, and activities of gross alpha in groundwater in Tres Hermanos-C2 Sandstone Member exceed EPA MCLs (Table D.8.14). The groundwater in the stratigraphically lower Tres Hermanos-C2 Sandstone Member has fewer constituents exceeding the EPA MCLs than the Tres Hermanos-C1 Sandstone Member. The smaller number of MCL exceedances in the Tres Hermanos-C2 Sandstone Member as compared to the overlying Tres Hermanos-C1 Sandstone Member can be attributed to the 10 to 15 foot thick bed of low permeable Mancos Shale that separates the two sandstone members. The sulfate anion is used as an indicator of the extent of tailings-related recharge in the Tres Hermanos-C2 Sandstone Member (Figure D.8.24). Monitor wells exhibiting recharge related to the tailings seepage as indicated by high sulfate concentrations are 676, 677, 779, 782, 784, 785 and 787. Concentration distributions for molybdenum and uranium are shown in Figures D.8.25 and D.8.26 for the February 1989 sampling round.

Appendix I organic constituents were not analyzed in groundwater samples collected from monitor wells screened in the Tres Hermanos-C1 and -C2 Sandstone, because they were not detected in the overlying alluvium/weathered Mancos Shale. The maximum observed concentrations for Appendix I inorganic constituents in groundwater samples collected from the Tres Hermanos-C1 and -C2 Sandstone Members are shown in Tables D.8.18 and D.8.19.

Tres Hermanos-B

Groundwater in the Tres Hermanos-B Sandstone does not appear to be affected by the seepage of leachate from the tailings pile at the Ambrosia Lake site and concentrations of all constitutents are at or below the proposed EPA MCLs except for nitrate (monitor well 678) and selenium (monitor wells 678 and 777) (Table D.8.15). The elevated concentrations of nitrate and selenium in groundwater samples from monitor wells 678 and 777 were detected during initial rounds of sampling and may be a result of contamination introduced into the groundwater during well drilling and installation operations. The concentration of selenium in a groundwater sample collected from monitor well 777 was below the proposed EPA MCL in a sampling round subsequent to the initial round. Monitor well 678 was recently installed and has only been sampled once; therefore, additional groundwater quality data is required to determine the trend in the nitrate concentration. Groundwater samples collected from monitor wells screened in the Tres Hermanos-B Sandstone were not analysed for Appendix I organic constituents because they were not detected in the overlying tailings (except for methyl ethyl ketone at a concentration below the method detection limit) or alluvium/weathered Mancos Shale. The maximum observed concentrations of Appendix I inorganic constituents are shown in Table D.8.20.

Westwater Canyon Member

A potential point of exposure (POE) for the tailing seepage is the Westwater Canyon Member, since groundwater from overlying units recharged by the tailings seepage (primarily the alluvium/weathered Mancos Shale and Tres Hermanos-C Sandstone) drains into the Westwater Canyon Member down mine shafts and vent holes. Mining activities not related to tailings seepage have introduced many other sources of contamination into the Westwater Canyon Member; thus, it is difficult to quantify changes in the groundwater quality of the Westwater Canyon Member that are attributable to the Ambrosia Lake site. The existing groundwater quality of the Westwater Canyon Member in the Ambrosia Lake region has been characterized by samples of mine water discharge pumped from the United Nuclear and Quivira Mining Company mines (Figure D.8.24 and Table D.8.8). Concentrations of cadmium, chromium, lead, molybdenum, selenium, silver, and uranium and activities of radium-226 and -228 and gross alpha exceed the EPA MCLs.

D.8.8 GEOCHEMICAL ENVIRONMENT

Geochemical characterization was conducted at the Ambrosia Lake site to determine the extent of migration of non-radiological hazardous constituents in soils beneath the tailings impoundment and areas of the tailings that will be removed. Geochemical properties of the subsoils and the lithologic matrix of the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone were investigated to determine their potential for control of contaminant concentrations in groundwater. Geochemical modeling was used to speciate analyses of tailings fluid and groundwater analyses from the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone to determine whether contaminants may occur as cations or anions that may be adsorbed by ion exchange. Saturation indices were calculated to determine if mineral solubility controls contaminant concentrations in tailings fluid and groundwater. Modeling was also performed to volumetrically mix tailings fluid at different proportions with mill make-up pond water to determine the origin of groundwater in the alluvium/weathered Mancos Shale and Tres Hermanos-C Sandstone. Lastly, concentrations of hazardous constituents in the Tres Hermanos-C and Westwater Canyon Member were compared to determine their potential influence on water quality in the Westwater Canyon Member from seepage migrating down mine shafts and vent holes into the Westwater Canyon Member.

Generally, non-radiological hazardous constituents are below detection limits in subsoils beneath the tailings. Although an alkaline pH front has advanced through subsoils beneath the tailings, the change in pH is relatively insignificant and does not affect the solubility of hazardous constituents in tailings seepage. The redox potential (Eh) of the tailings fluid and groundwater in the alluvium/weathered Mancos Shale is relatively oxidizing. Groundwater becomes slightly less oxidizing as it enters the Tres Hermanos-C Sandstone and flows down dip. However, the change in Eh between the alluvium/weathered Mancos Shale and the Tress Hermanos-C Sandstone does not significantly affect the solubility of most hazardous constituents. The most important hazardous constituents in the tailings pore fluid and groundwater in the alluvium/weathered Mancos Shale, including nitrate, selenium, molybdenum and uranium, occur as anions. Adsorption by the cation exchange process is not an important process of removal of most of these hazardous constituents. Dilution of tailings seepage by mill make-up water that drained into the alluvium/weathered Mancos Shale reduces concentrations of these hazardous constituents in groundwater in the alluvium/weathered Mancos Shale. Geochemical simulation of this volumetric mixing of waters suggests that groundwater in the alluvium/weathered Mancos Shale is derived largely from these two sources. Because the concentration of nitrate, a conservative species, is the same in groundwater in the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone, much of the groundwater in the Tres Hermanos-C Sandstone is probably derived from seepage from the alluvium/weathered Mancos Shale. A comparison of concentrations of hazardous constituents in the Tres Hermanos-C Sandstone with those in the Westwater Canyon Member indicates that seepage down mine shafts and vent holes will not influence water quality in the Westwater Canyon

Member. Concentrations of most hazardous constituents in the Tres Hermanos-C Sandstone are lower than those in the Westwater Canyon Member and the relative rate of groundwater underflow in the Westwater Canyon Member compared to the Tres Hermanos-C Sandstone assures that no water quality impacts will occur in the Westwater Canyon Member.

D.8.8.1 Non-radiologic hazardous constituents in soils

Non-radiological hazardous constituents in soils are defined as elements listed in Appendix I of 40 CFR 192 that are not regulated under the radiation protection standards. Information regarding concentrations of residual non-radiologic constituents in soils is important because it must be demonstrated that the remedial action under Subpart A can be decoupled from groundwater cleanup under Subpart B of 40 CFR 192. It must be demonstrated that residual levels of non-radiological hazardous constituents will not cause groundwater cleanup standards to be exceeded. Because Ambrosia Lake groundwater is classified as limited use and supplemental standards apply, groundwater restoration is not anticipated and cleanup is not applicable. However, a pathways analysis must be performed to demonstrate that there is a low risk of potential harm to human health or the environment. In order to conduct the pathways analysis, a field program was conducted and previous site characterization data were reviewed to provide information on the distribution of non-radiological hazardous constituents in subsoils in the vicinity of the tailings. This information was used as the basis of the pathways analysis discussed in Addendum A of Appendix E.

As part of a field program, the DOE obtained split spoon samples of tailings and subsoils beneath the tailings in the northern portion of the pile. Locations of these borings are shown on Figure D.8.27. These samples were analyzed for non-radiologic hazardous constituents using dionized water extraction method (DOE, 1986) and EPA methods of analysis. The data from the DOE field program suggest that concentrations of most non-radiological hazardous constituents are below detection limits in tailings subsoils. However, concentrations of molybdenum were observed above detection limits down to two feet below the tailings in one borehole (#683).

D.8.8.2 Geochemical conditions

Geochemical properties of the soils and lithologic matrix of the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone were investigated to determine their potential for control of contaminant concentrations in groundwater. In terms of controls on contaminant migration, the base-neutralization potential of the alluvium and the weathered Mancos Shale and the Tres Hermanos-C Sandstone have not been exhausted. This is confirmed by the near-neutral pH values measured in groundwater samples obtained from the Tres Hermanos-C Sandstone (D.8.21). Percolation of alkaline tailings leachate to groundwater has not raised the pH of groundwater in monitor wells completed in the alluvium/weathered Mancos Shale, or the Tres Hermanos-C Sandstone subjacent to the tailings pile. Profiles of pH as a function of depth beneath the tailings, constructed from data obtained from Markos and Bush (1983), are presented in Table D.8.21. Locations of the borings are shown on Figure D.8.27. Generally the profiles indicate that there is an alkaline pH front in the soils beneath the tailings. However, because the soil pH only changes from 10.4 to 8.5 within the soil horizon, the change in pH is sufficiently small that there is no concentration of non-radiolgoical hazardous constituents with the soils above detection limits as a function of depth.

As part of the DOE field program, the Eh was measured in the tailings pore fluid and groundwater in both the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone. The Eh of the tailings pore fluids and groundwater in the alluvium/weathered Mancos Shale is oxidizing. Groundwater in the subcrop area of the Tres Hermanos-C Sandstone may be oxidizing but then changes to less oxidizing conditions down dip. Longmire (1984) reports that the Eh of groundwater in the Westwater Canyon Member is also oxidized. A summary of Eh and pH conditions in the tailings and each water-bearing unit of interest is provided in Table D.8.22.

Visual inspection of core samples obtained during the DOE field program suggests that mineral assemblages in the alluvium/weathered Mancos Shale are typical of weakly oxidized conditions. Calcite, gypsum, and ferric oxyhydroxides are mineral assemblages found in the alluvium/weathered Mancos Shale. However, under the less oxidizing conditions in the Tres Hermanos-C Sandstone, the mineral assemblages of calcite and pyrite are present along with locally occurring solid organic matter.

D.8.8.3 Geochemical modeling

Geochemical modeling was used to determine the dissolved species of hazardous constituents in groundwater, using analyses from the tailings pore fluids, alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone. This speciation helps to determine whether contaminants may occur as cations or anions that may be absorbed by ion exchange. However, ion exchange was not modeled and is only discussed qualitatively. Saturation indices (SI) were calculated to determine whether solubility controls contaminant concentrations in tailings fluid and groundwater. Modeling was also performed to mix tailings pore fluid at different proportions with mill make-up pond water to determine if the origin of groundwater in the alluvium/weathered Mancos Shale is due to these two fluids.

Computer code

The FORTRAN computer code PHREEQE (Parkhurst et al., 1980) was used in the geochemical modeling. PHREEQE solves simultaneous equations that describe the equilibrium chemical reactions that may occur in a specified water. Lindberg (Department of Geology, University of Colorado) has expanded the thermochemical data base in this version of PHREEQE for dissolved species and solid compounds of uranium and molybdenum; however, only nitrate, selenium, uranium, and molybdenum were modeled. Jacobs Engineering Group personnel have run test cases using this version of PHREEQE to verify that the geochemical calculations are accurate and in agreement with the non-modified PHREEQE code (Parkhurst et al., 1980). All modeling results are on file at the UMTRA Project Office in Albuquerque, New Mexico.

Speciation of tailings fluids and groundwater

Geochemical modeling was used to speciate analyses of tailings pore fluid and groundwater analyses from the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone to determine whether contaminants may occur as cations or anions that may be absorbed by ion exchange. Input to the PHREEQE model included laboratory chemical analyses, and field measurements of temperature, pH and Eh. Distribution of species of selected hazardous constituents are presented in Table D.8.23. Selenium, nitrate, molybdenum, and uranium all are present as anions under physiochemical conditions found within the tailings and groundwaters. Anion exchange or sorption sites usually occur in concentrations that are about 10% of those of cation exchange sites. Only molybdenum seems to be removed or atenuated within the groundwaters of the Tres Hermanos-C Sandstone. Nitrate concentrations are relatively the same in groundwater in the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone indicating that a large percentage of groundwater in the Tres Hermanos-C Sandstone is derived from seepage from the alluvium/weathered Mancos Shale.

Saturation indices

Saturation indices for different minerals were calculated to determine whether minerals that contain hazardous constituents will precipitate from solution, causing a resulting decrease in concentration. The saturation index for a given mineral and solid phase is defined as:

$$SI = \log_{10} \frac{\text{activity product (AP)}}{\text{solubility product } (K_{sp})}$$

When the calculated satuation index for a mineral or solid compound is greater than zero, the solution is oversaturated, and that mineral should precipitate from solution to reach equilibrium. If the saturation index is equal to zero, a solution is in equilibrium with a particular mineral. Conversely, when the saturation index is less than zero, a solution is undersaturated with a particular mineral and that mineral is predicted to dissolve.

Saturation indices for minerals in the tailings, alluvium/weathered Mancos Shale, the Tres Hermanos-C Sandstone and the Westwater Canyon Member are presented in Table D.8.24. All of the solutions are oversaturated with respect to calcite, hematite, and the ferric oxyhydroxides that include lepidocrocite, ferric hydroxide, and goethite. This implies that iron will precipitate from solution under all conditions. The prediction of the precipitation of ferric oxyhydroxide in groundwater is verified by their existence in core samples.

The precipitation of ferric oxyhydroxide is important because they control the concentration of selenium and molybdenum via adsorption (Rai and Zachara, 1984; Leckie et al., 1980). Selenium and molybdenum may also be adsorbed onto solid organic carbon. Adsorption on ferric oxyhydroxide may account for the partial removal of uranium and molybdenum from tailings pore fluid during mixing with mill make-up pond water in the alluvium/weathered Mancos Shale.

Origin of groundwater

The PHREEQE geochemical code was used to calculate the results of mixing different amounts of tailings solutions with mill make-up water to try to delineate the origin of groundwater in the alluvium/weathered Mancos Shale. If observed analyses of water quality and the alluvium/weathered Mancos Shale could be simulated by this mixing calculation, it is reasonable that most of the groundwater derived from these sources and that the condition of saturation within the alluvium/weathered Mancos Shale was created by uranium processing activities.

Three possible sources of recharge water available to the alluvium/weathered Mancos Shale include tailings seepage, seepage through the unlined mill water make-up pond, and recharge from arroyos from Roman Hill. The water quality of tailings seepage was represented by lysimeter analytical data. Mill make-up water was primarily mine water discharge derived from the mean Westwater Canyon Member concentrations. The water quality of recharge from arroyos from Roman Hill is undetermined.

Mill make-up water and tailings pore fluid were mixed in different ratios (0.30, 0.40, 0.50, 0.60, and 0.65) and equilibrated with calcite, gypsum and ferric oxyhydroxide to simulate aqueous concentrations in groundwater the alluvium/weathered Mancos Shale. The mean concentrations of water quality parameters used in the mixing calculations, the predicted concentrations and the observed mean concentrations in the analyses of alluvium/weathered Mancos Shale groundwater are presented in Table D.8.25. Based on comparison of the log molalities of chloride, sulfate, nitrate and uranium, a mixing ratio of approximately 1:3 best simulates the mixture of tailings fluids and mill make-up water that combined to create the condition of saturation in the alluvium/weathered Mancos Shale.

From the modeling of mixing ratios, it appears that dilution of tailings seepage by mill make-up water is the major process for the decrease in concentrations of nitrate and uranium. Concentrations of selenium are higher in the alluvium/weathered Mancos Shale than in the tailings pore fluids suggesting that naturally occuring selenium may be released into solution.

D.8.8.4 Potential influence of seepage on water quality in the Westwater Canyon member

Concentrations of hazardous constituents in the Tres Hermanos-C Sandstone and the Westwater Canyon Member were compared to determine the potential influence on water quality in the Westwater Canyon Member from seepage migrating down mine shafts and vent holes into the Westwater Canyon Member. Mean concentrations of hazardous constituents in the Tres Hermanos-C Sandstone and the Westwater Canyon Member are presented in Table D.8.26. Generally, mean concentrations of hazardous constituents in the Tres Hermanos-C Sandstone are lower than in the Westwater Canyon Member. Exceptions to this generalization are chromium, nitrate, vanadium, and gross alpha activity. Concentrations of chromium in the Tres Hermanos-C Sandstone are only slightly higher than that found in the Westwater Canyon Member. Nitrate and gross alpha activity slightly exceed the MCLs in mean analyses of groundwater from the Tres Hermanos-C Sandstone. Although vanadium is one and one half orders of magnitude higher in concentration in the Tres Hermanos-C Sandstone than in the Westwater Canyon Member, the relative rates of groundwater flow in the formations is such that any seepage into the Westwater Canyon Member would be substantially diluted. This suggests that seepage of Tres Hermanos-C Sandstone groundwater into the Westwater Canyon Member will produce no increase in the concentrations of hazardous constituents in the Westwater Canyon Member.

D.8.9 GROUNDWATER USE, VALUE, AND ALTERNATIVE SUPPLIES

The primary water supply in the Ambrosia Lake area is groundwater. Surface water is not a viable water supply source as all streams in the area are intermittent and are sediment-laden during the short periods of storm runoff. Groundwater in the Ambrosia Lake area is used by the uranium mining industry, and for domestic and ranch supplies. Present groundwater use is approaching pre-1955 levels because of the recent decline of the uranium mining industry (Brod and Stone, 1981). A discussion of groundwater use as it relates to supplemental standards is contained in Addendum A of Appendix E.

Uranium industry

Uranium mine dewatering beginning in the mid-1950s withdrew large amounts of groundwater to facilitate ore removal from the Westwater Canyon Member. Early pumping totalled 24 million gallons per day for the Ambrosia Lake, San Mateo, and Bluewater-Milan areas (Cooper and John, 1968). The New Mexico Environmental Improvement Division (NMEID, 1980) indicated pumpage from mines just in the Ambrosia Lake area ranged from eight to 13 million gallons per day. After 20 years of pumping, potentiometric levels were lowered hundreds of feet in the eastern Ambrosia Lake area (Brod and Stone, 1981). Most of the pumped water was discharged to surface drainages where it evaporated or infiltrated to recharge the shallow sediments.

The pumped mine water was considered a resource and was used by the mills for ore processing and by a few ranchers in the area for domestic and stock purposes. It was not until the late 1970s that the quality of mine discharge water came under scrutiny by the state, and settling ponds and water treatment were required. It was also at this time that the quanity of the water pumped was monitored.

Presently, the uranium industry is retiring the mines in Ambrosia Lake. Ore is being actively mined at only one mine. However, many of the mines are still being dewatered and some water presently pumped from active and inactive mines is being reinjected during a low-scale solution recovery of uranium from the mined-out areas. If uranium production becomes economically viable in the future, water usage would probably be similar in nature and extent as in the past during the 1950s through the 1970s.

Domestic

The nearest municipality operating a public water supply is San Mateo, 10 miles southeast of the Ambrosia Lake site (Figure D.8.28). In the community of Ambrosia Lake, a few private wells draw water from the Westwater Canyon Member and the alluvium along San Mateo Creek to obtain water for domestic use. In the early 1970s, deeper wells in the Westwater Canyon Member went dry due to mine pumpage, and Kerr-McGee (Quivira) constructed a pipeline to supply domestic needs in the area.

There are no domestic wells completed in any of the Tres Hermanos Sandstones or within the alluvium in the Ambrosia Lake valley. The valley includes the area between San Mateo Mesa and Mesa Montonosa north of New Mexico Highway 53, and within three miles of the tailings site (Figure D.8.28). The Tres Hermanos Sandstones and alluvium do not yield an adequate groundwater supply of acceptable quality for domestic use.

Most of the domestic wells in the Ambrosia Lake valley have been abandoned (Brod and Stone, 1981). A total of nine active wells are known to be within five miles of the Ambrosia Lake site and five are used for domestic purposes (Table D.8.21). Two domestic wells supply homes at the junction of New Mexico Highways 53 and 509 (Figure D.8.28), 4.5 miles southwest of the site. One well completed in the Westwater Canyon Member is reported (Marquez, 1985) to be 300 feet deep and supplies poor quality (very hard) water to three residences. The depth of the second well is unknown.

The third domestic well is on the Phil Harris ranch, which is one mile northwest of the junction of New Mexico Highway 509 and New Mexico Highway 53 (Figure D.8.28). This well was completed in the Westwater Canyon Member or in deeper formations and supplies the ranch house. The Berryhill ranch, three miles northwest of the Ambrosia Lake site, has an 800-foot-deep well completed in the Westwater Canyon Member. This well went dry in the early 1970s, and Quivira has supplied the ranch water via a pipeline from their Section 17 mine. A second Berryhill Ranch well was listed in Brod and Stone (1981), but the ranch foreman revealed that the water for the trailer, house, and 15 horses is supplied entirely by the Quivira pipeline (Baughman, 1985a).

The fifth well, reportedly belonging to a Mr. Jerry Elkins, is used for both domestic and stock purposes (NMEID, 1987). This well is believed to be completed in the Westwater Canyon Member of the Morrison Formation and is located approximately 3.5 miles northwest of the Ambrosia Lake tailings pile.

Stock

There are five ranch headquarters in the Ambrosia Lake area. The Berryhill and Harris lands are used for grazing and three wells were reportedly used for stock supply (see Table D.8.28). None of these stock wells were completed in the shallow aquifers including the alluvium or the Tres Hermanos Sandstones (Baughman, 1985b). All stock supply wells in the valley were completed in the Westwater Canyon Member or San Andres Limestone at depths of 500 to 3000 feet. There is no present or historical irrigation within the Ambrosia Lake valley and demand is anticipated to remain low because the area is poorly suited for farming due to low precipitation, poor soils, and limited good-quality groundwater.

Prior to mining, there was little development in the Ambrosia Lake area and limited use of groundwater. The twenty-year period of uranium mining and milling activity spurred temporary development of the valley and drastically altered the quality and quantity of groundwater resources. Future groundwater development in the valley is expected to be even more limited than premining times due to the unknown residual effects of the mining industry. There is an extremely small potential for future use of shallow groundwater because of the large areal extent of naturally poor-quality water, limited yield capability, artificially saturated zones drying up, regional contamination of the groundwater due to mine dewatering, and discharge of mill effluents. These factors qualify the groundwater to be designated as Class III (limited use).

The value of existing groundwater use within a five-mile radius of the site can be estimated by multiplying existing use by current water rates. The total use of groundwater from the nine wells (five domestic wells and four livestock wells), assuming each well pumps at an average rate of one gallon a minute, is 389,000 gallons per month (4.7 million gallons per year). The commercial water supply rate being charged in 1989 by the municipal water supply of Milan, New Mexico, is $14.60 per month for the service connection, plus $.96 per 1000 gallons (Henley, 1989). Thus the value of existing groundwater use, based on Milan municipal water supply rates, is $6233 per year.

D.8.10 CLIMATE

Meteorological data for the Ambrosia Lake area are presented in Section D.9 of this document. The following is a summary of data pertinent to the hydrologic cycle.

The regional climate is classified as semiarid and continental. The climate is characterized by low precipitation, abundant sunshine, low relative humidity, and moderate temperatures with large diurnal and annual ranges (QMC, 1981).

Most of the precipitation in the project area occurs during the late summer thunderstorm season, although there is considerable monthly and annual variation in total rainfall. Long-term precipitation measurements made at the Floyd Lee Ranch near San Mateo (13 miles southeast of the tailings site) and three other regional stations are presented in Table D.9.4. Long-term annual average precipitation for San Mateo is 8.83 inches with a maximum annual precipitation of 13.55

inches in 1956. August was the wettest month with an average of 2.13 inches. Most of the winter precipitation in this area falls as snow (QMC, 1981).

The mean annual lake evaporation in the area is 54 inches. Seventy-two percent of the annual evaporation occurs from May through October (NOAA, 1979).

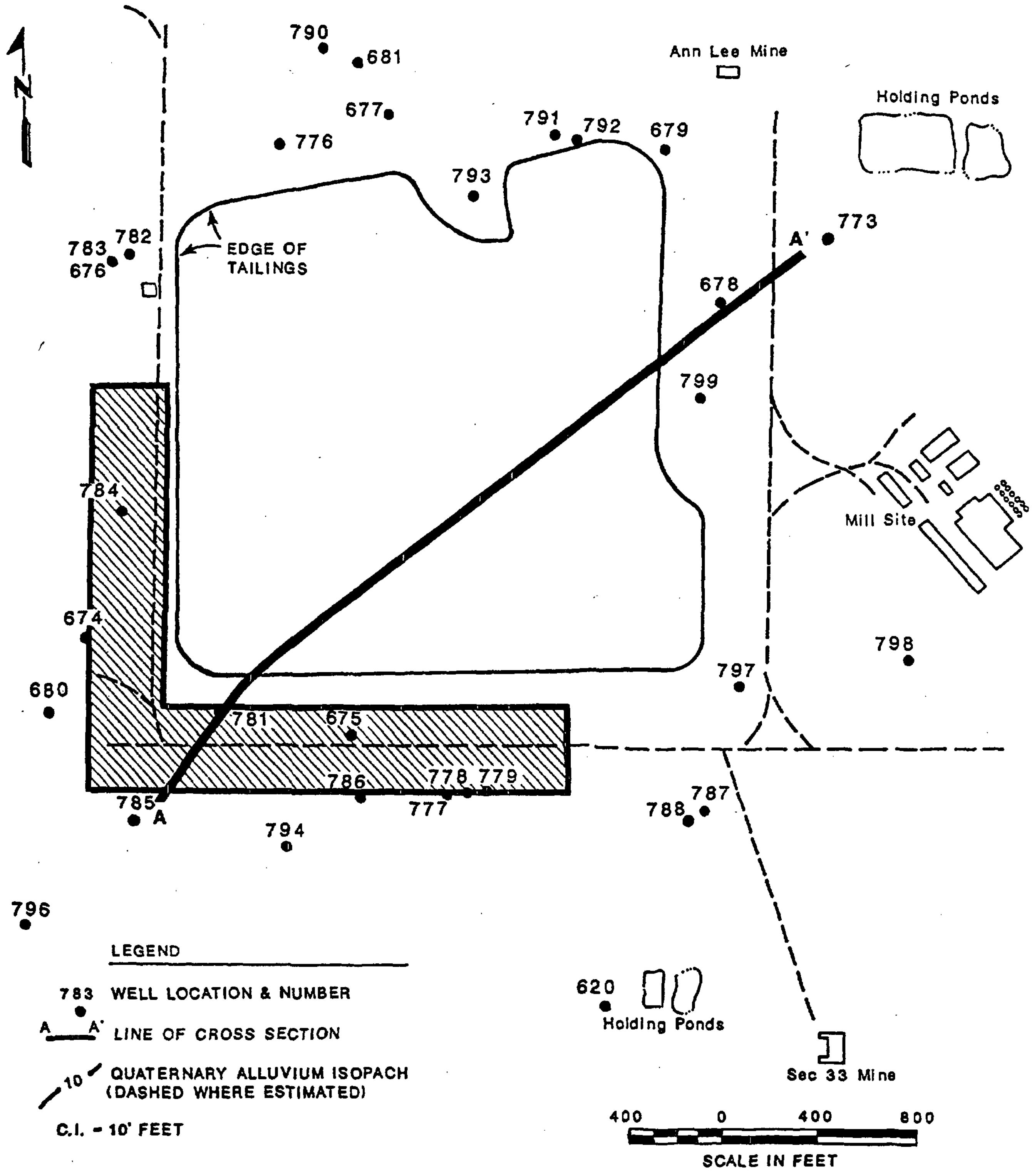


FIGURE D.8.1
LOCATION OF CROSS SECTION, DOE MONITOR WELLS AND POINT OF COMPLIANCE

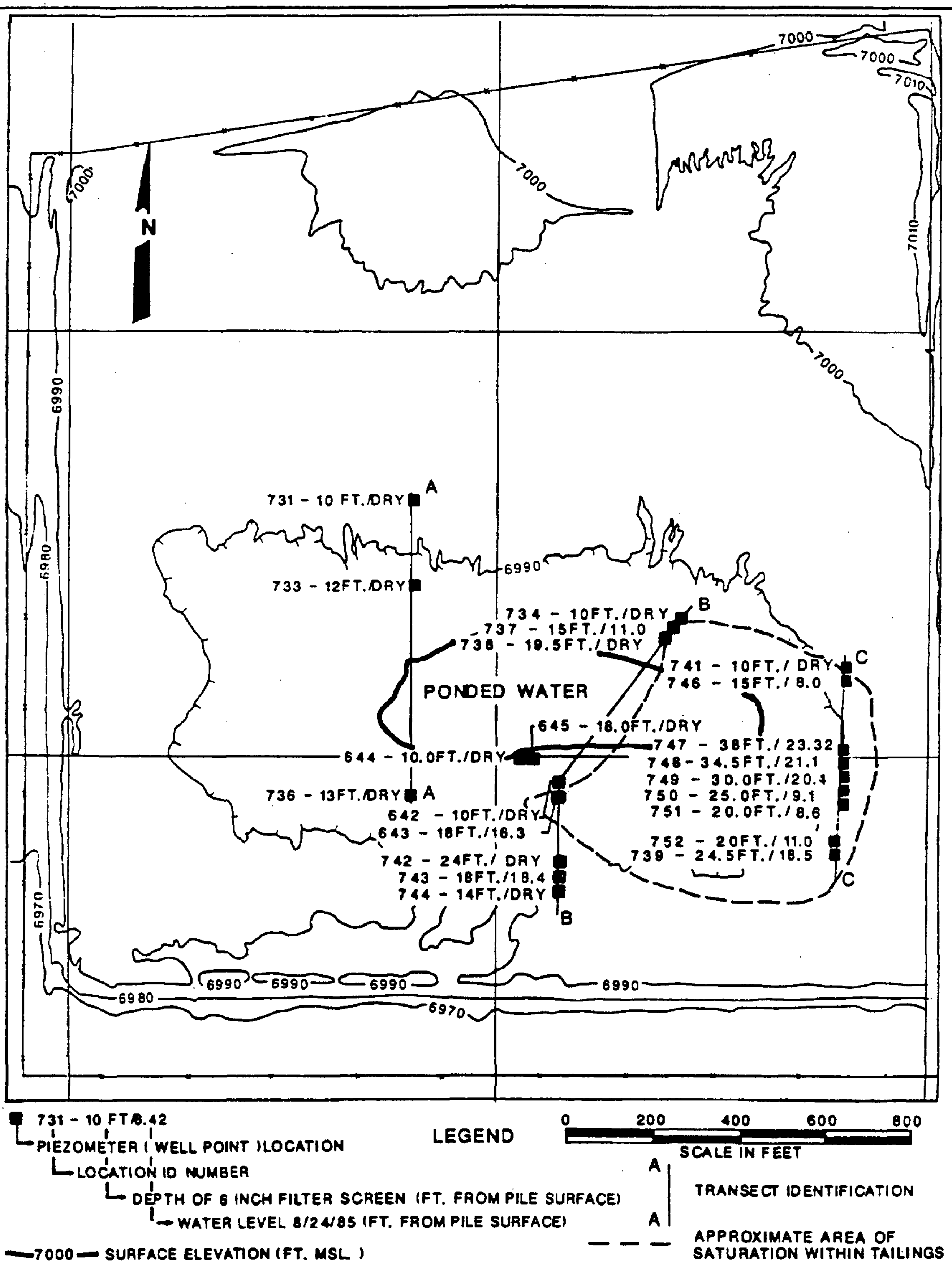


FIGURE D.8.2 LOCATIONS OF ON-PILE WELL POINTS

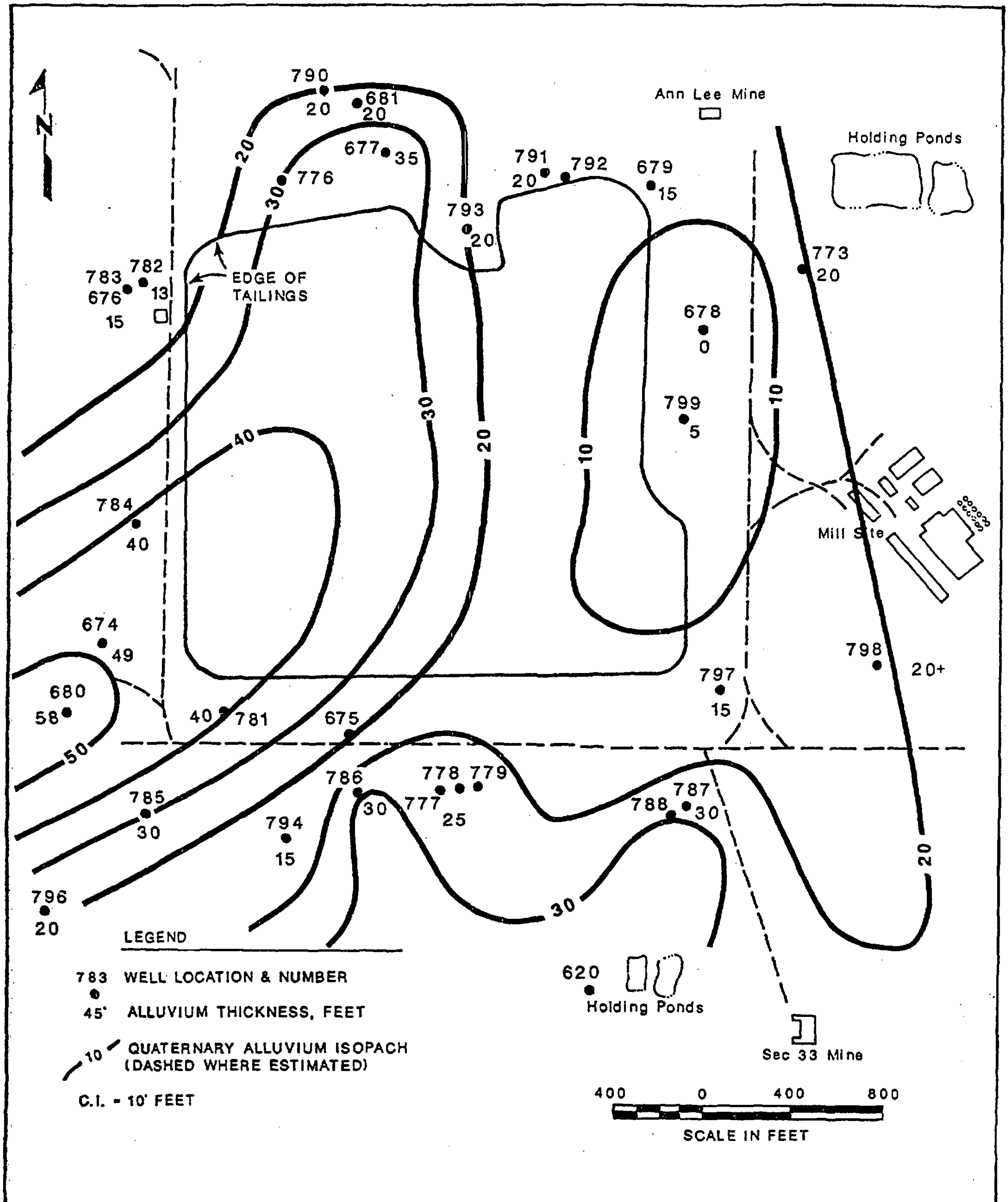
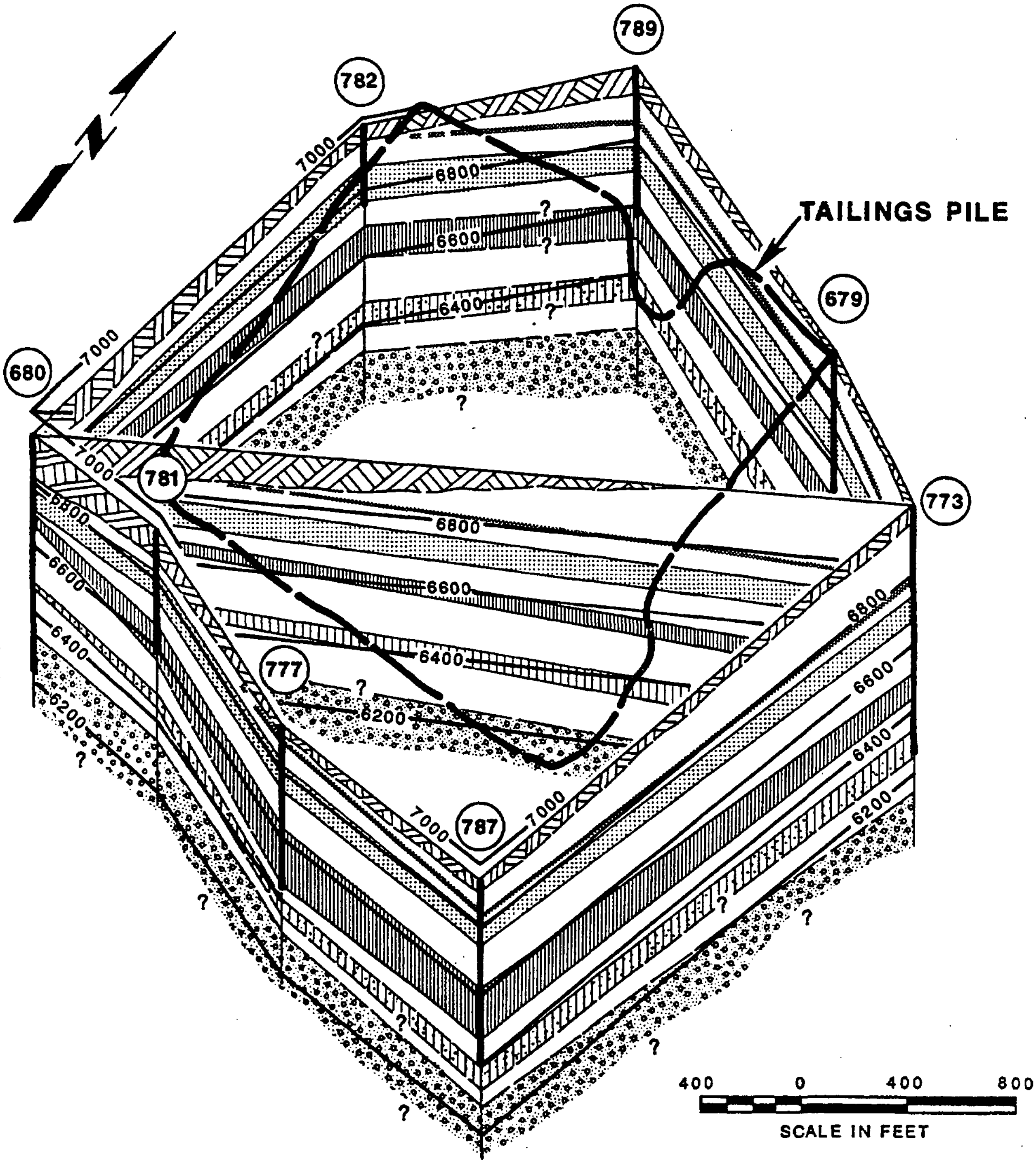


FIGURE D.8.3
QUATERNARY ALLUVIUM ISOPACH
AMBROSIA LAKE SITE, NEW MEXICO



LEGEND

ALLUVIUM/WEATHERED MANCOS SHALE	TRES HERMANOS - A SANDSTONE MEMBER
MANCOS SHALE	DAKOTA SANDSTONE
TRES HERMANOS - C1 SANDSTONE MEMBER	—6200— ELEVATION MARKER IN FT. ASL
TRES HERMANOS - C2 SANDSTONE MEMBER	— — —— CONTACT, DASHED WHERE ESTIMATED
TRES HERMANOS - B SANDSTONE MEMBER	(680) WELL LOCATION AND NUMBER

FIGURE D.8.4
GEOLOGIC FENCE DIAGRAM OF AMBROSIA LAKE SITE, NEW MEXICO

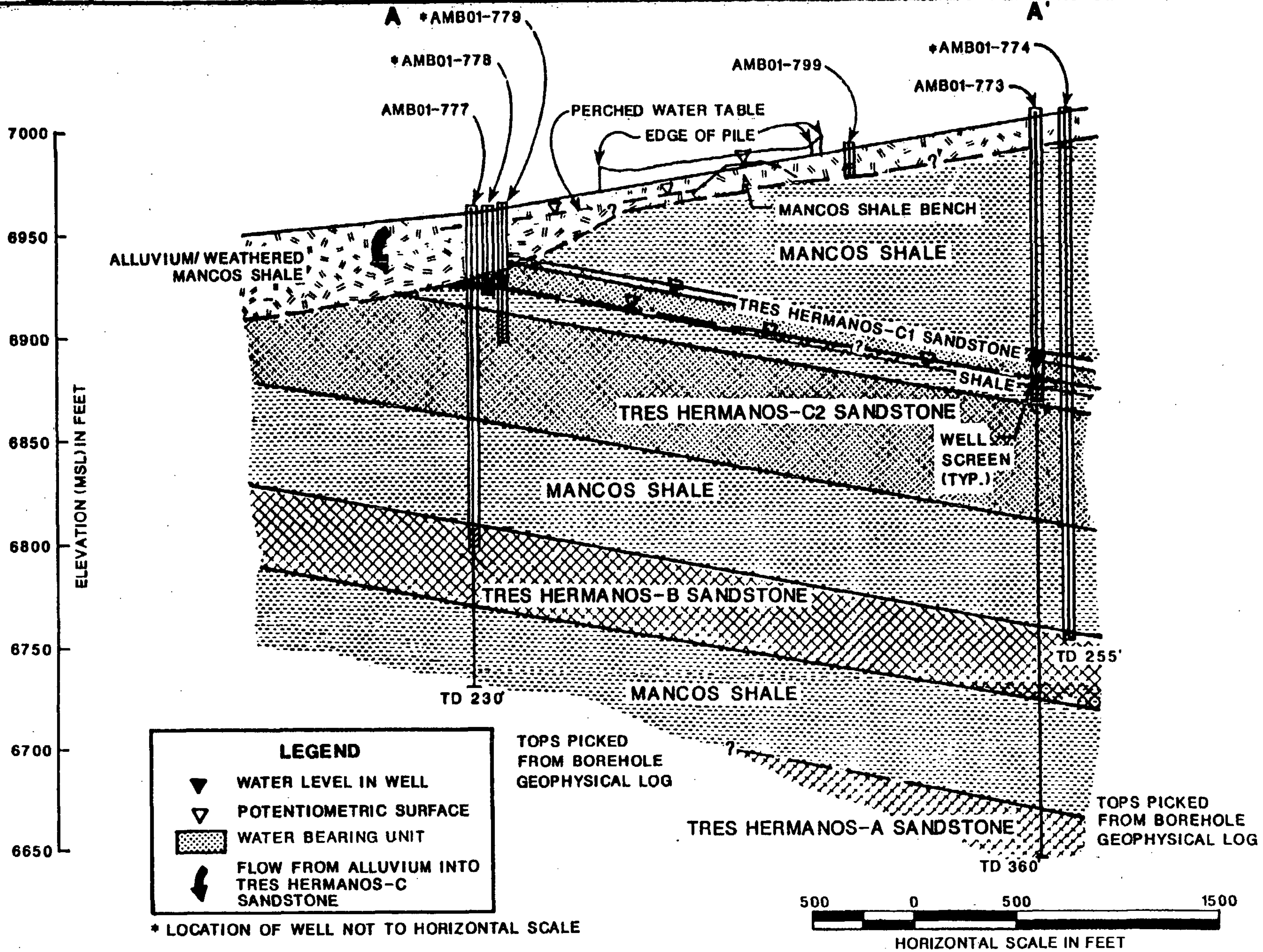


FIGURE D.8.5 HYDROGEOLOGIC CROSS SECTION A-A'

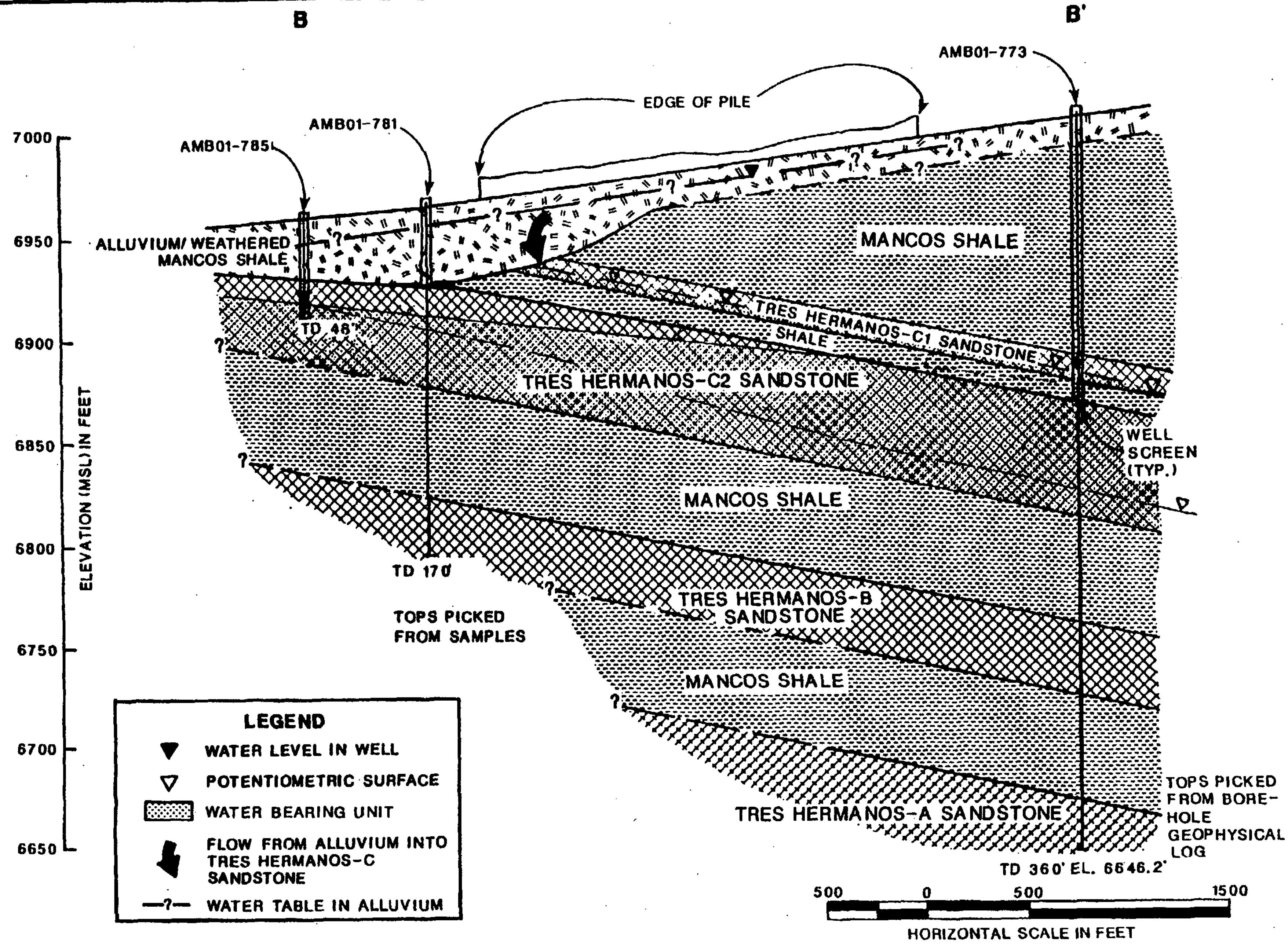


FIGURE D.8.6 HYDROGEOLOGIC CROSS SECTION B-B'

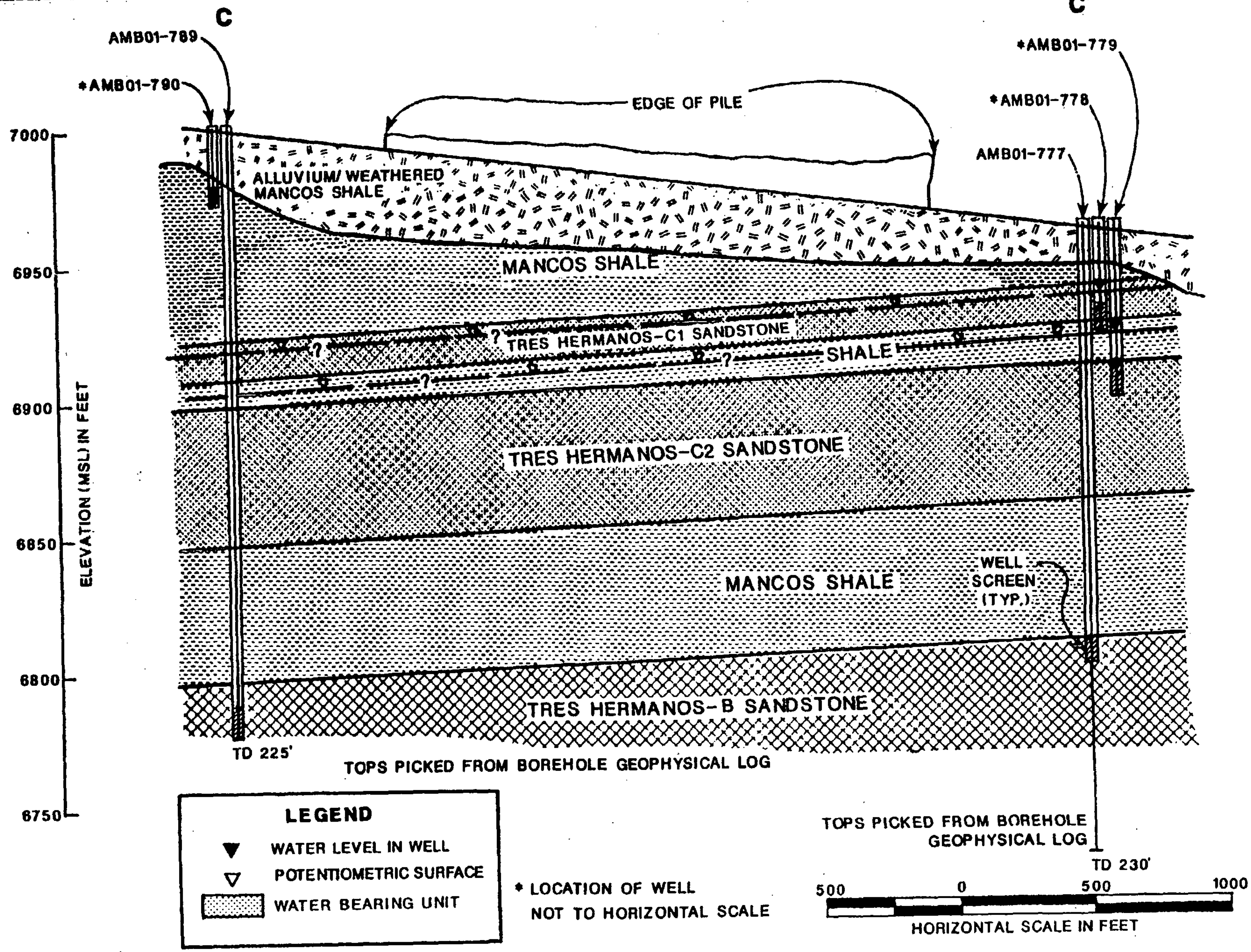


FIGURE D.8.7 HYDROGEOLOGIC CROSS SECTION C–C'

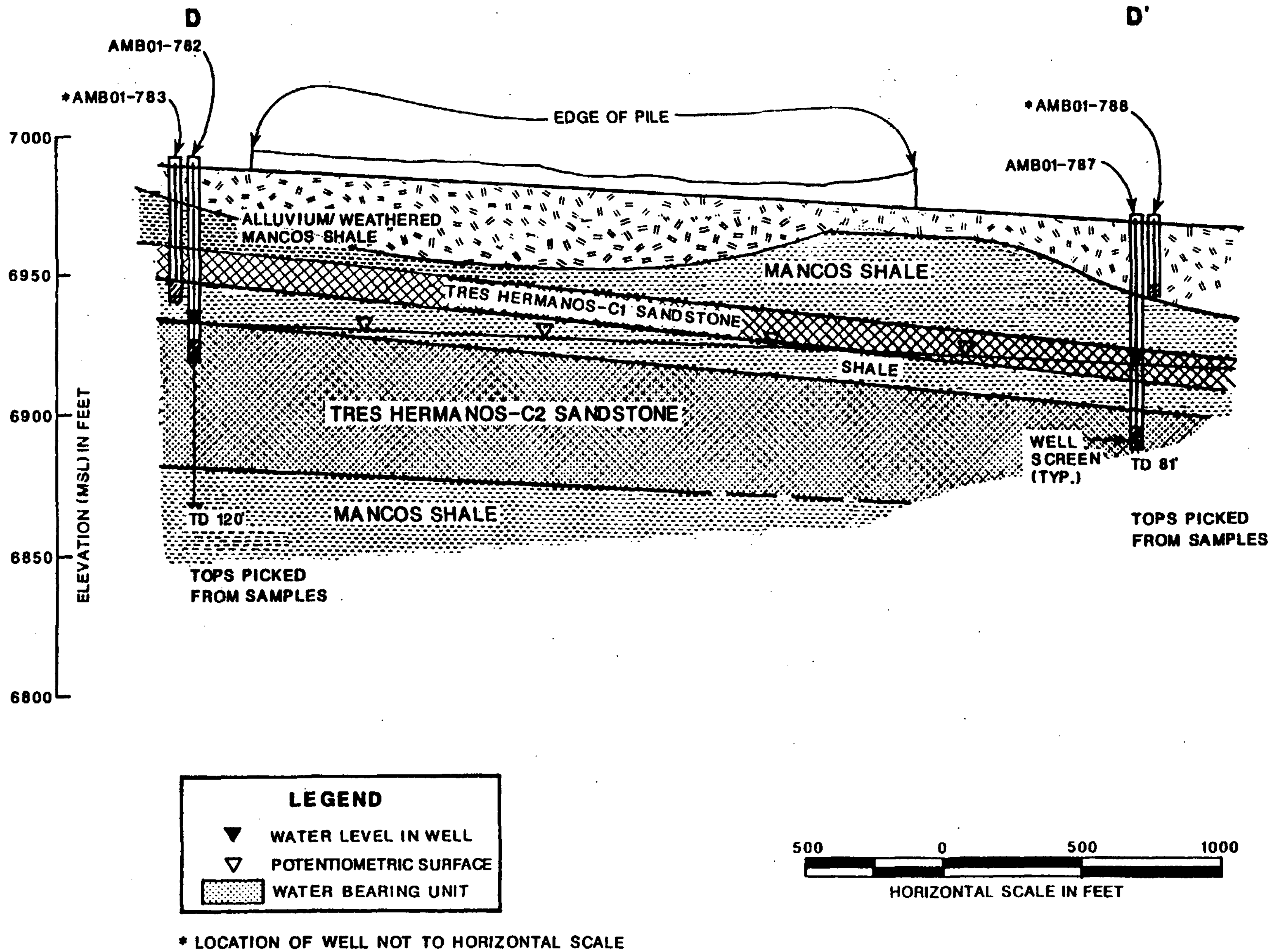


FIGURE D.8.8 HYDROGEOLOGIC CROSS SECTION D-D'

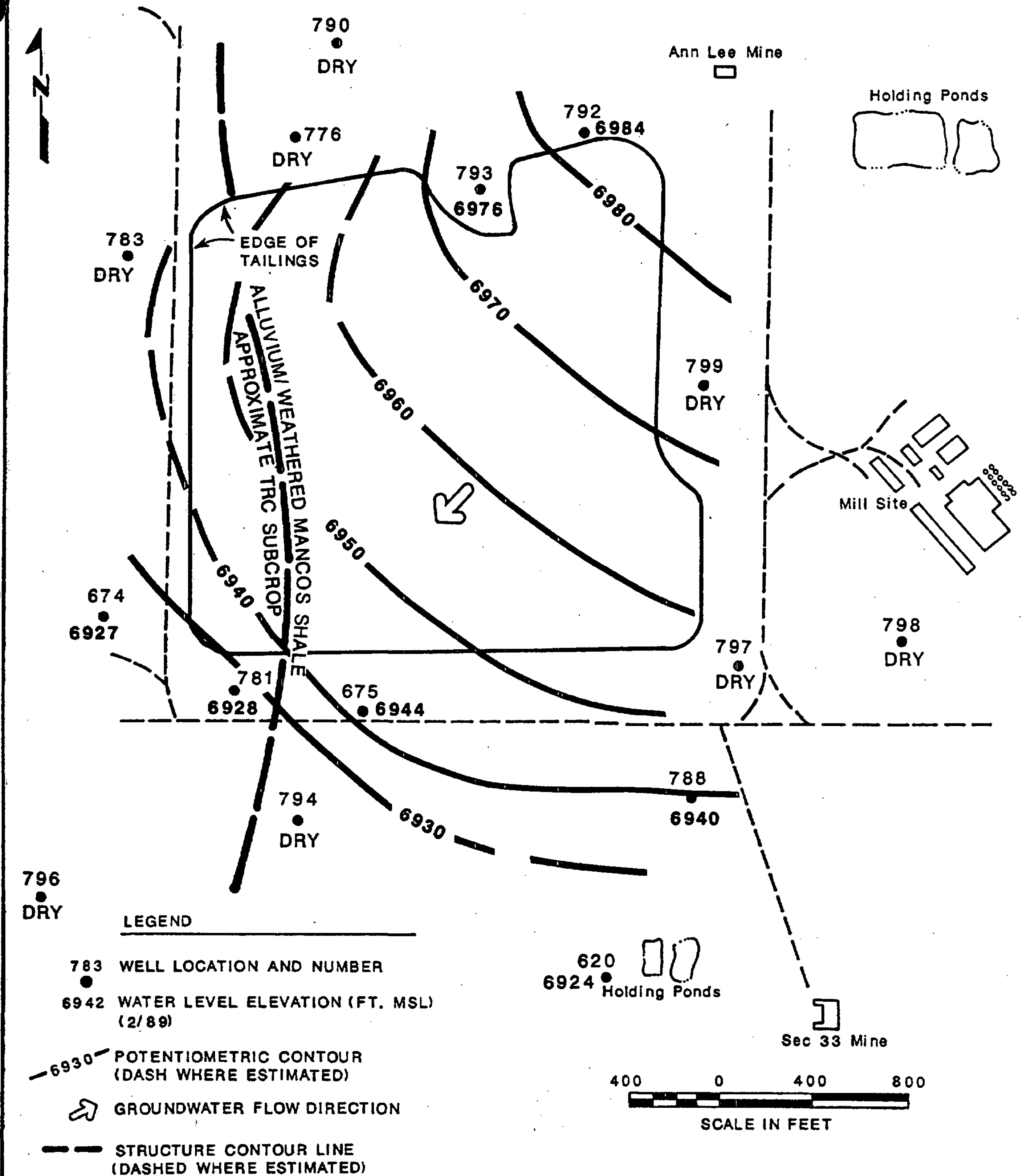


FIGURE D.8.9
WATER TABLE MAP FOR ALLUVIUM/WEATHERED MANCOS SHALE AMBROSIA LAKE SITE, NEW MEXICO

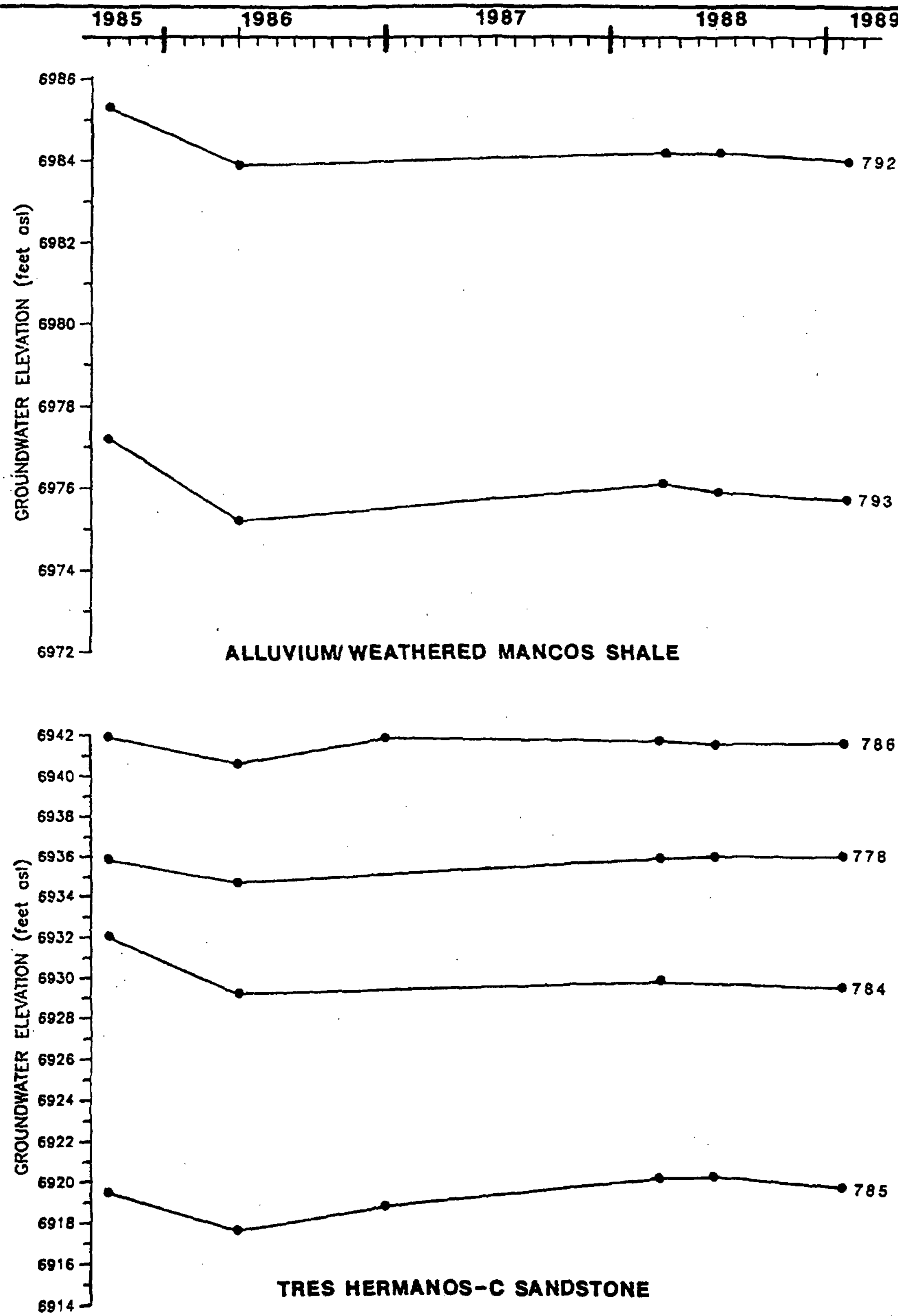


FIGURE D.8.10
HYDROGRAPH FOR SELECTED WELLS
AT THE AMBROSIA LAKE SITE, NEW MEXICO

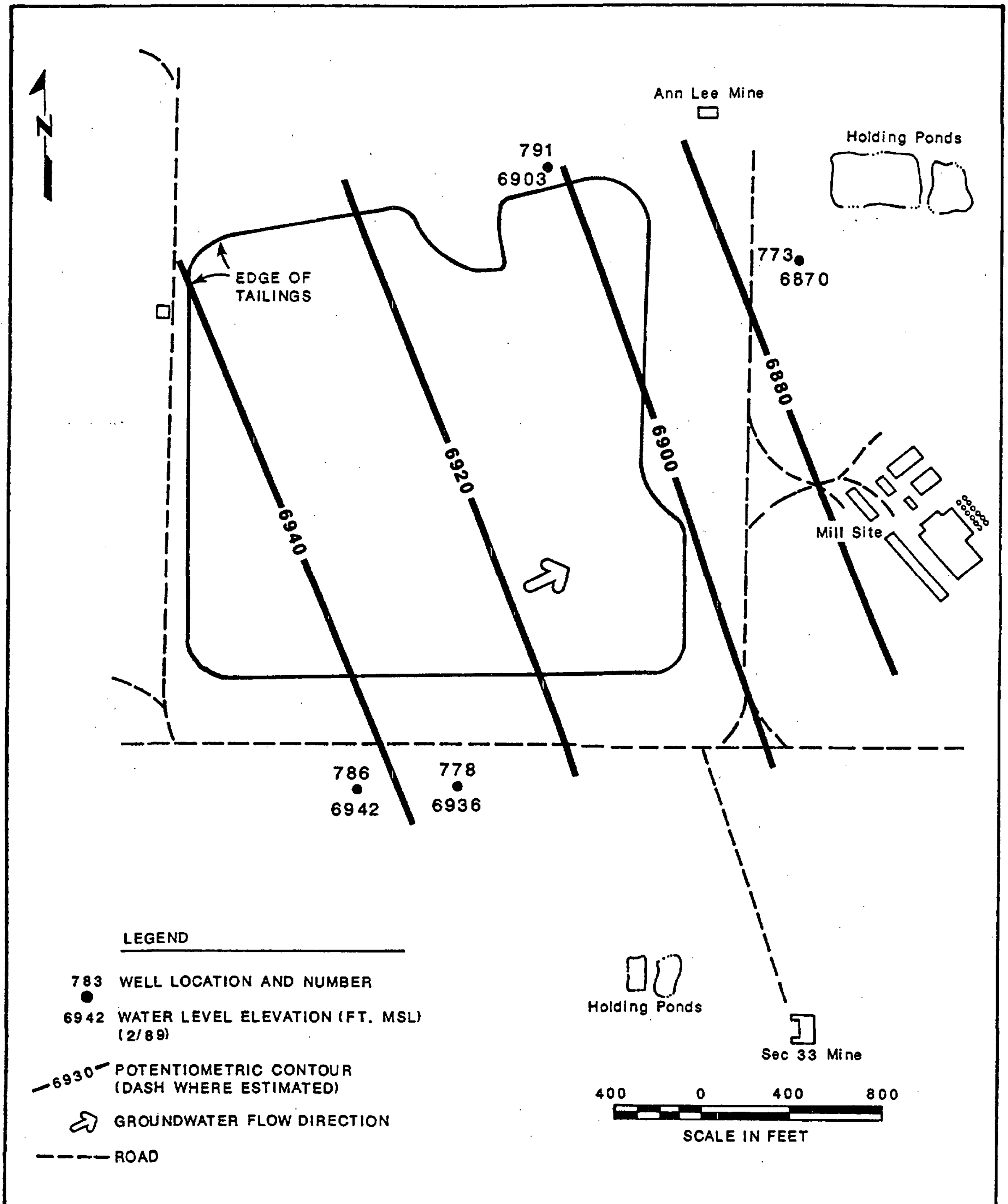


FIGURE D.8.11

EQUIPOTENTIAL MAP FOR TRES HERMANOS-C1 SANDSTONE AMBROSIA LAKE SITE, NEW MEXICO

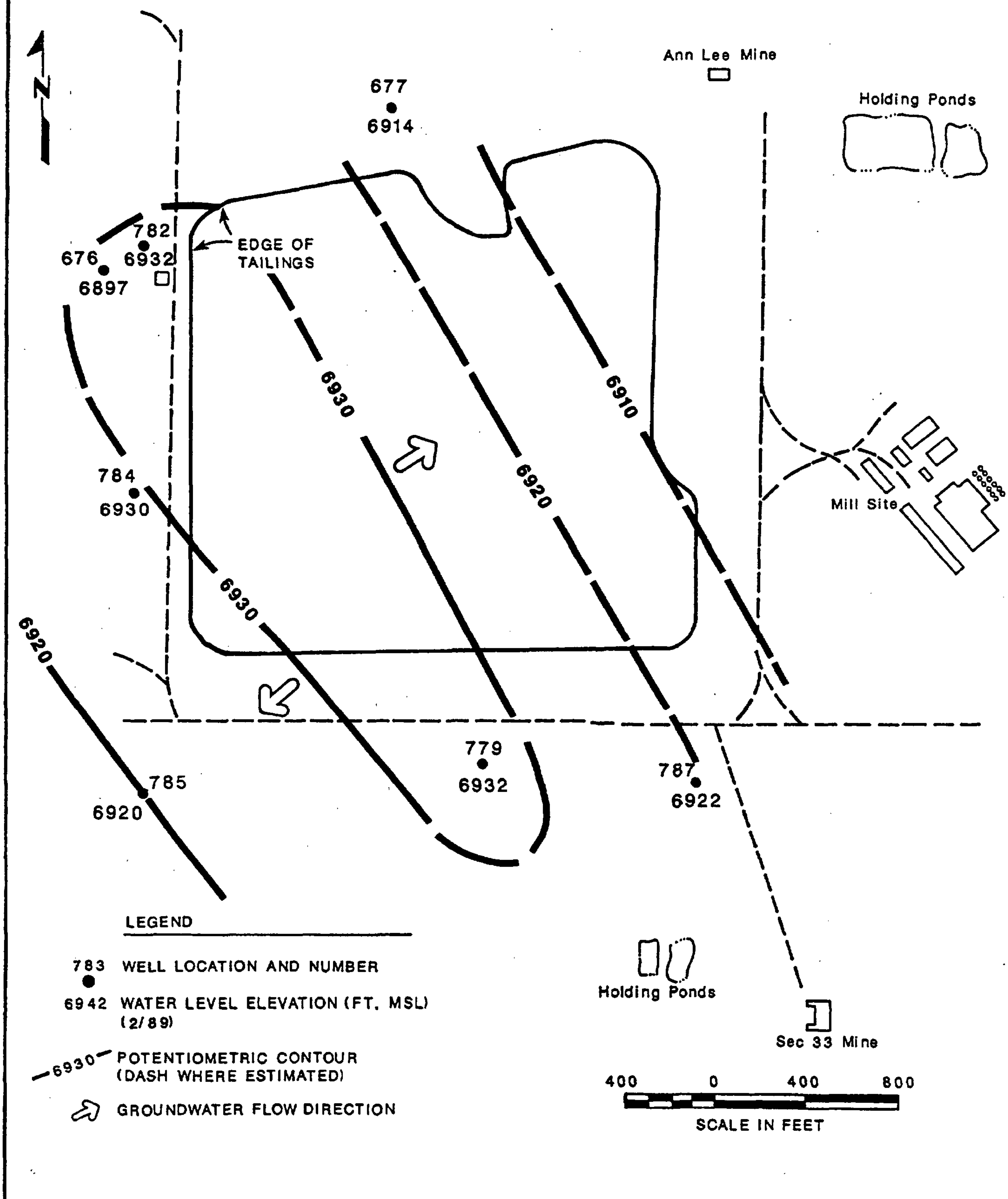


FIGURE D.8.12
EQUIPOTENTIAL MAP FOR TRES HERMANOS-C2 SANDSTONE

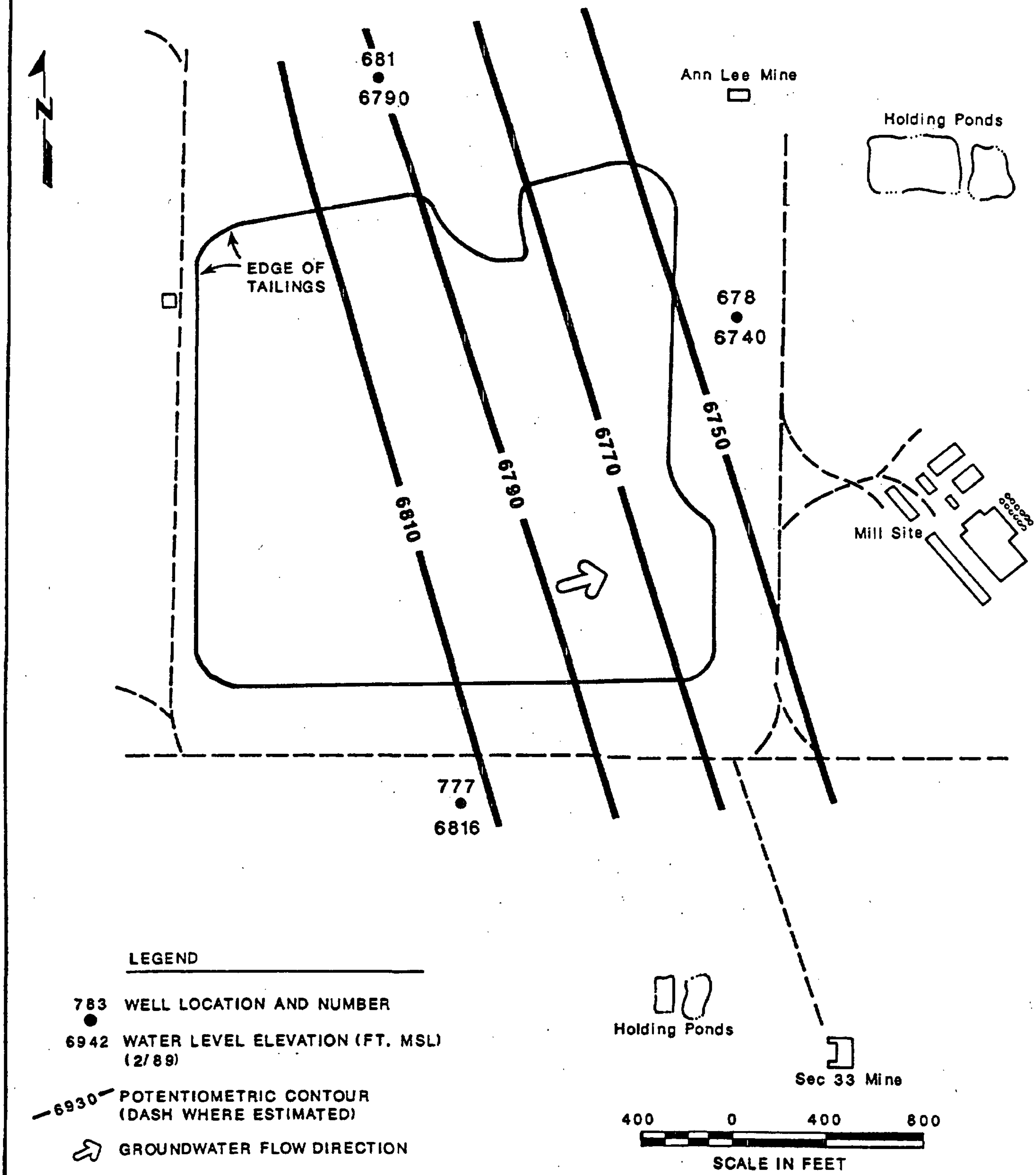


FIGURE D.8.13

EQUIPOTENTIAL MAP FOR TRES HERMANOS- B SANDSTONE AMBROSIA LAKE SITE, NEW MEXICO

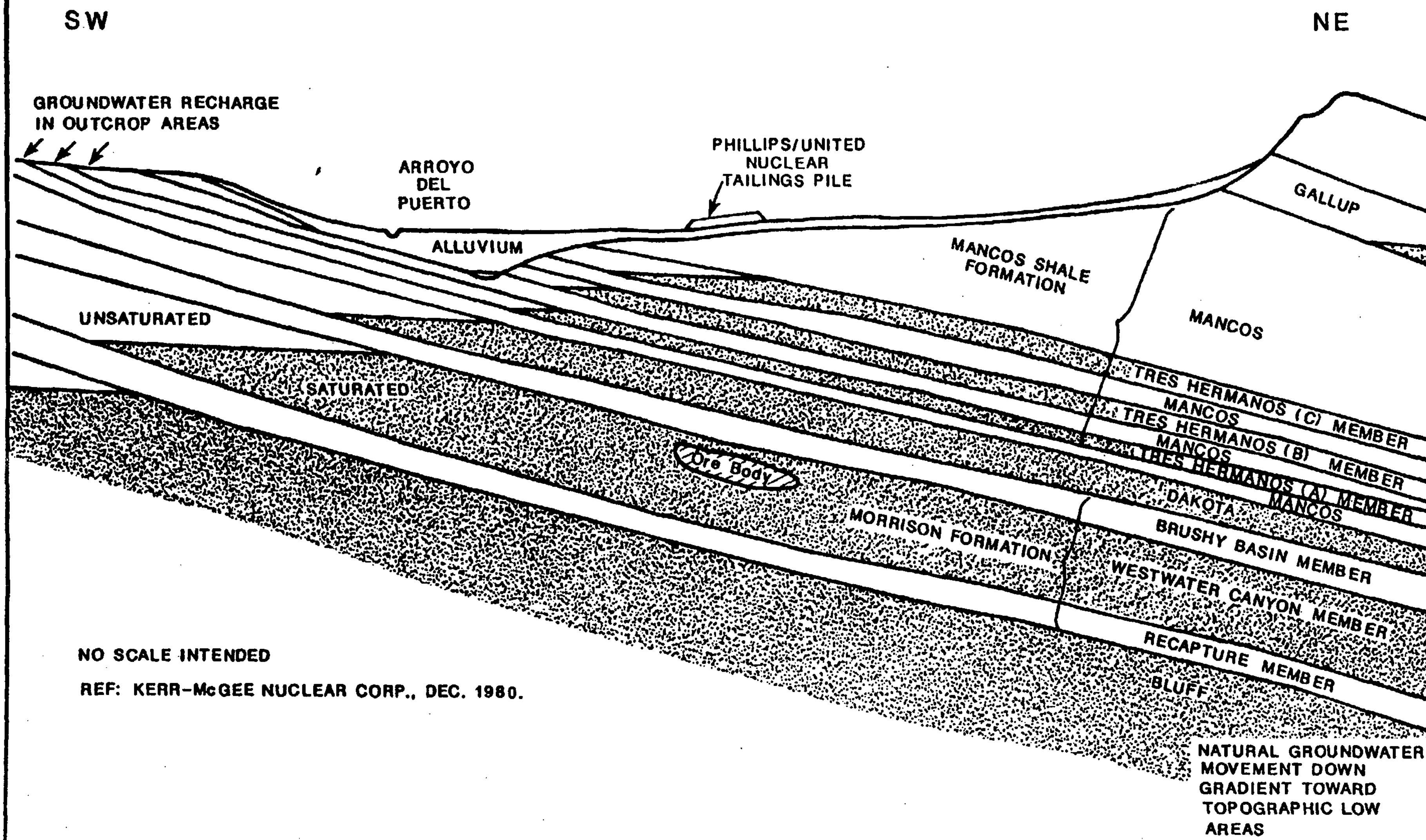


FIGURE D.8.14

SW–NE CROSS SECTION SHOWING GENERALIZED PRE–MINING CONDITIONS AT THE AMBROSIA LAKE SITE, NEW MEXICO

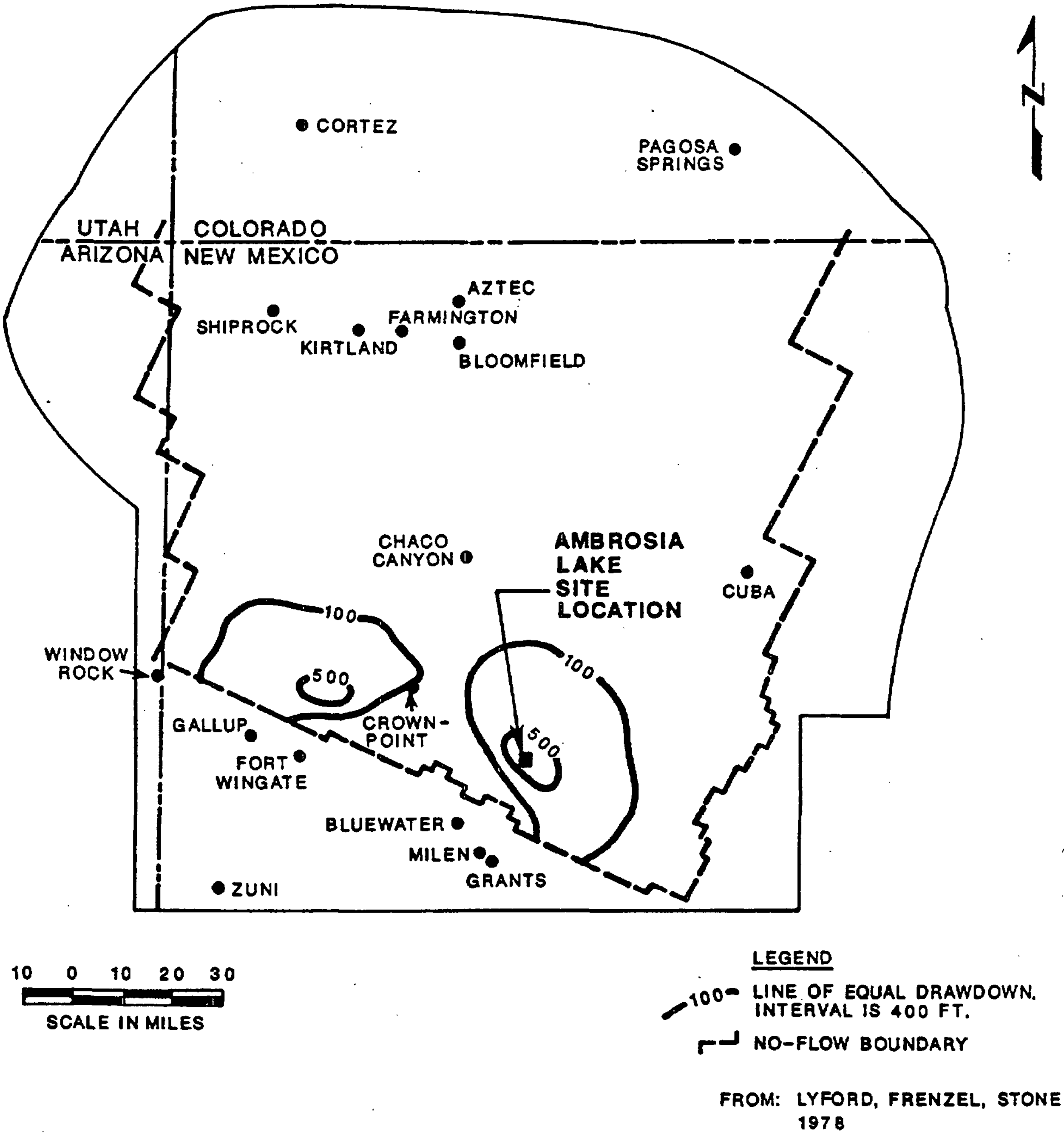
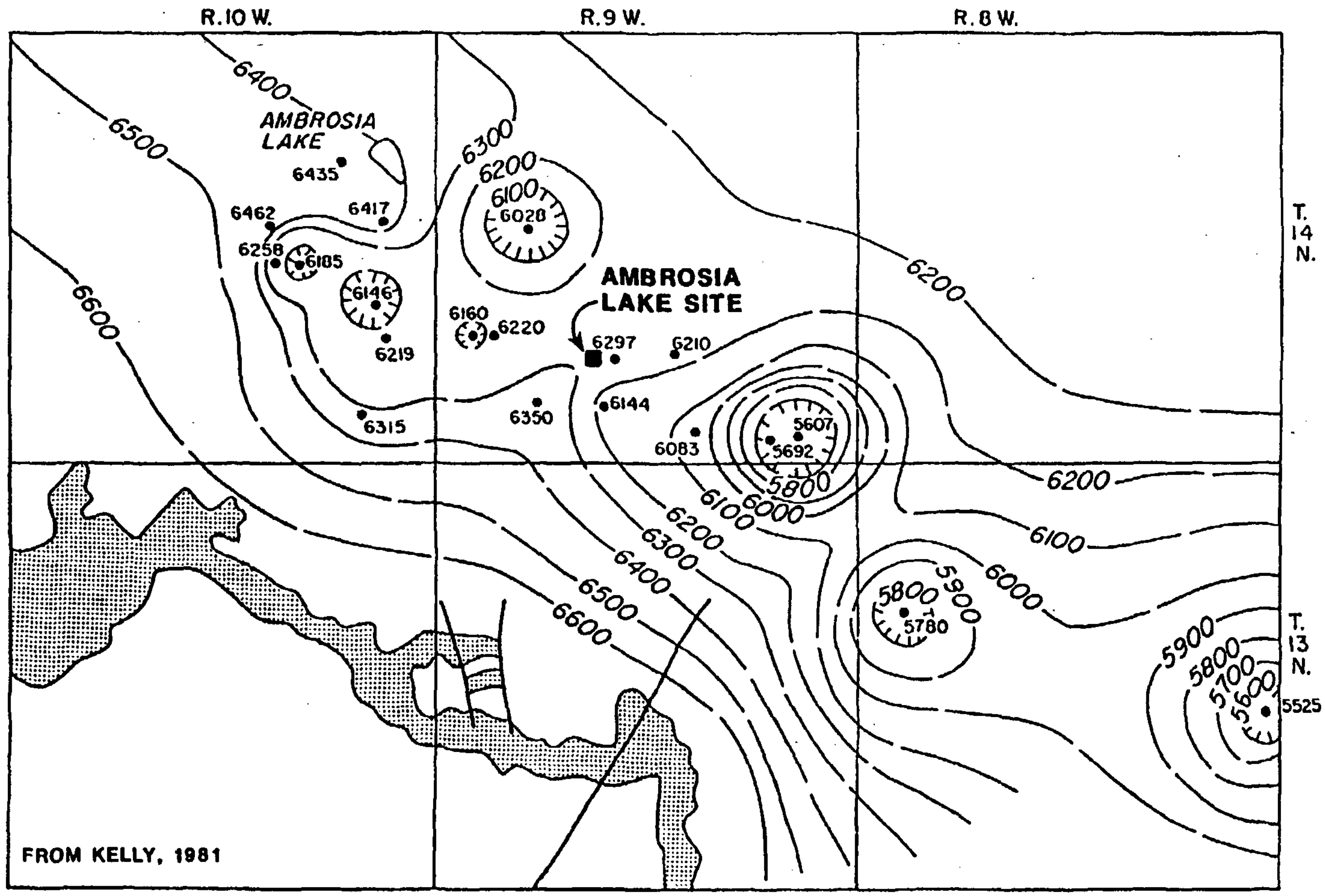


FIGURE D.8.15

MODELED DRAWDOWN IN THE MORRISON FORMATION BY THE YEAR 1980 AMBROSIA LAKE SITE, NEW MEXICO



NOTE: CONTOUR INTERVAL, 100 FT.; STIPPLED AREA REPRESENTS THE OUTCROP OF THE MORRISON FORMATION.

FIGURE D.8.16

POTENTIOMETRIC CONTOURS FOR THE WESTWATER CANYON MEMBER IN THE AMBROSIA LAKE AREA, 1979

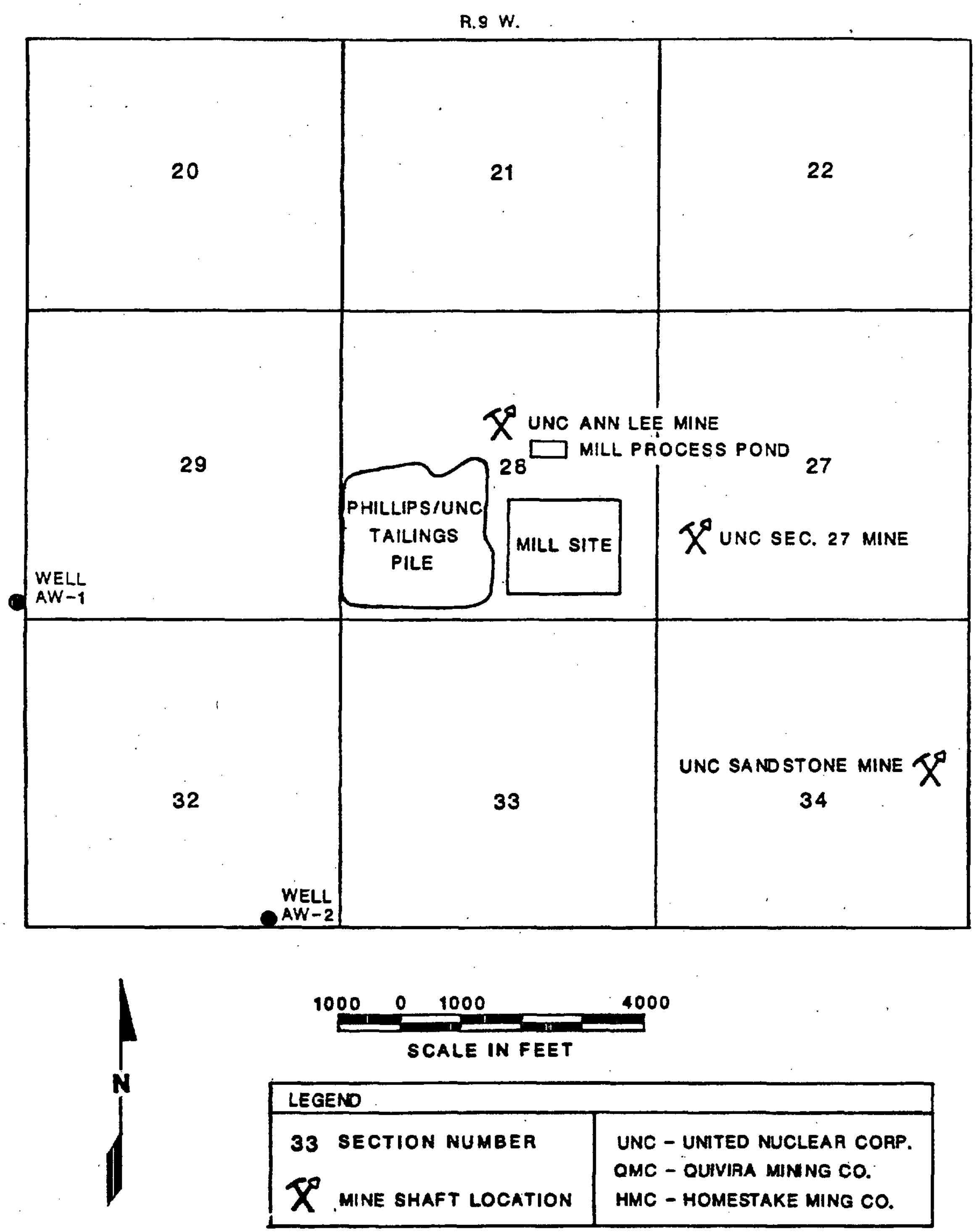
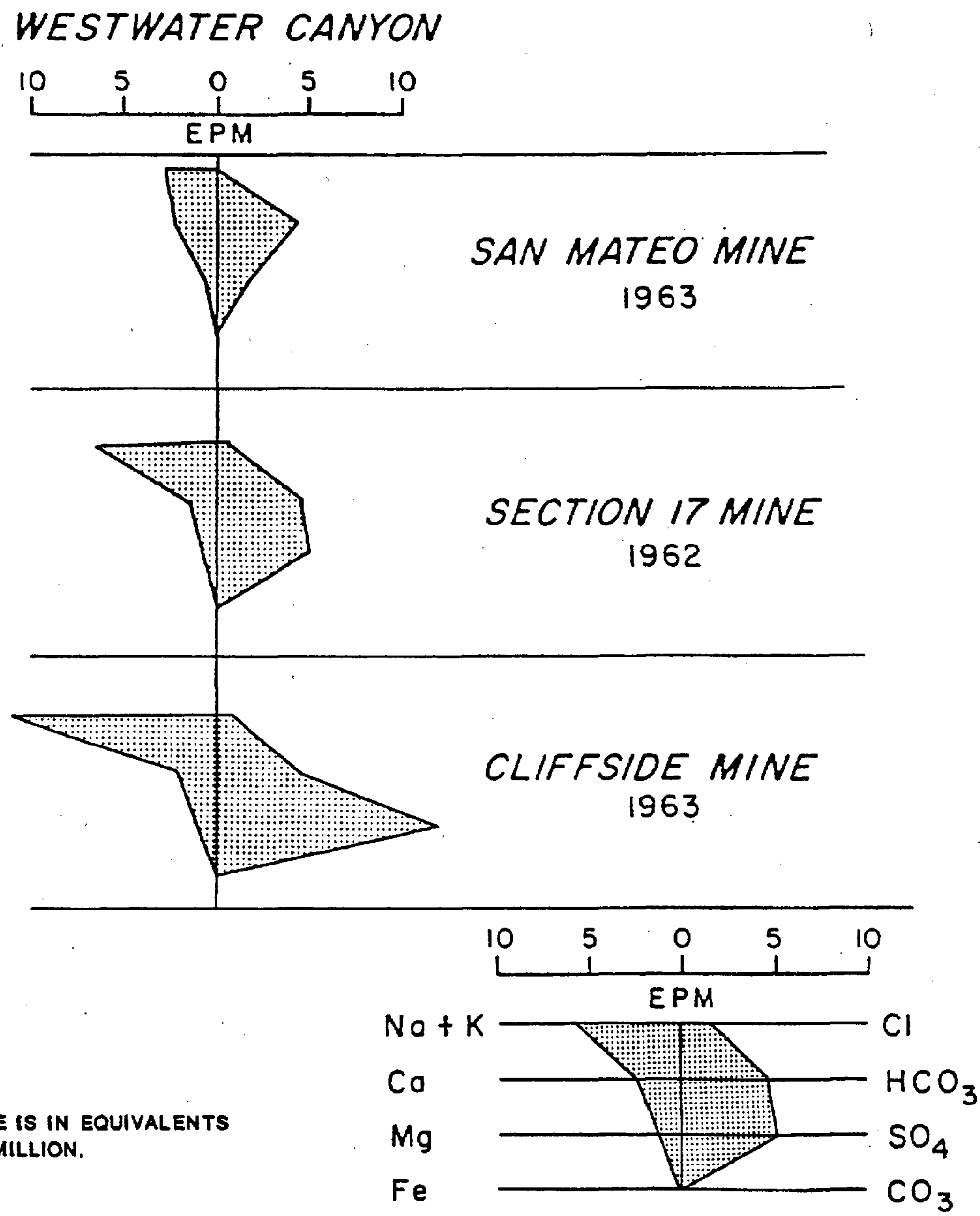


FIGURE D.8.17
LOCATIONS OF PHILLIPS/UNITED NUCLEAR MINES AND WELLS AW-1 AND AW-2



NOTE: SCALE IS IN EQUIVALENTS PER MILLION.

FROM KELLY, 1981

FIGURE D.8.18
STIFF DIAGRAM SHOWING WATER QUALITY FOR THE WESTWATER CANYON MEMBER

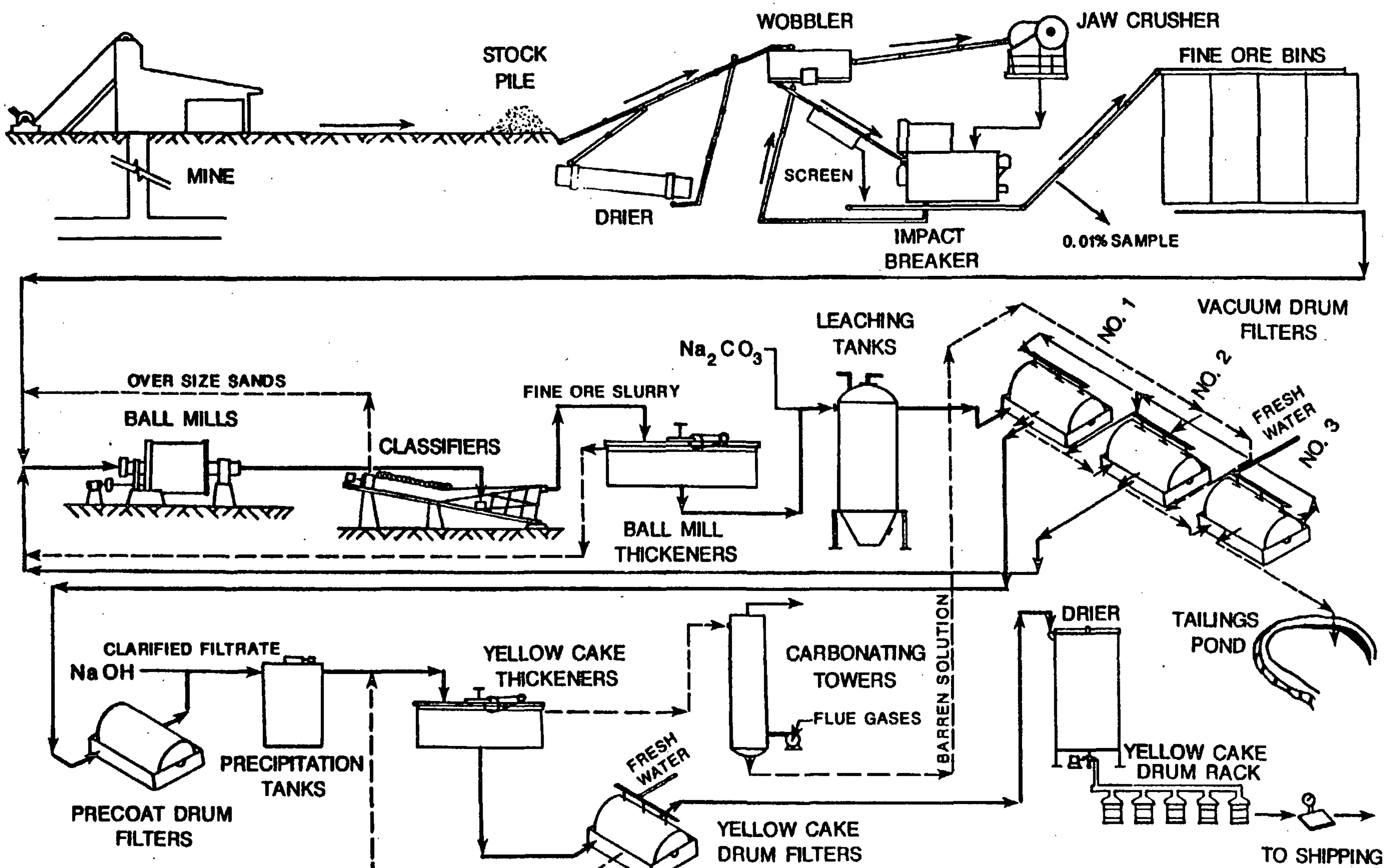
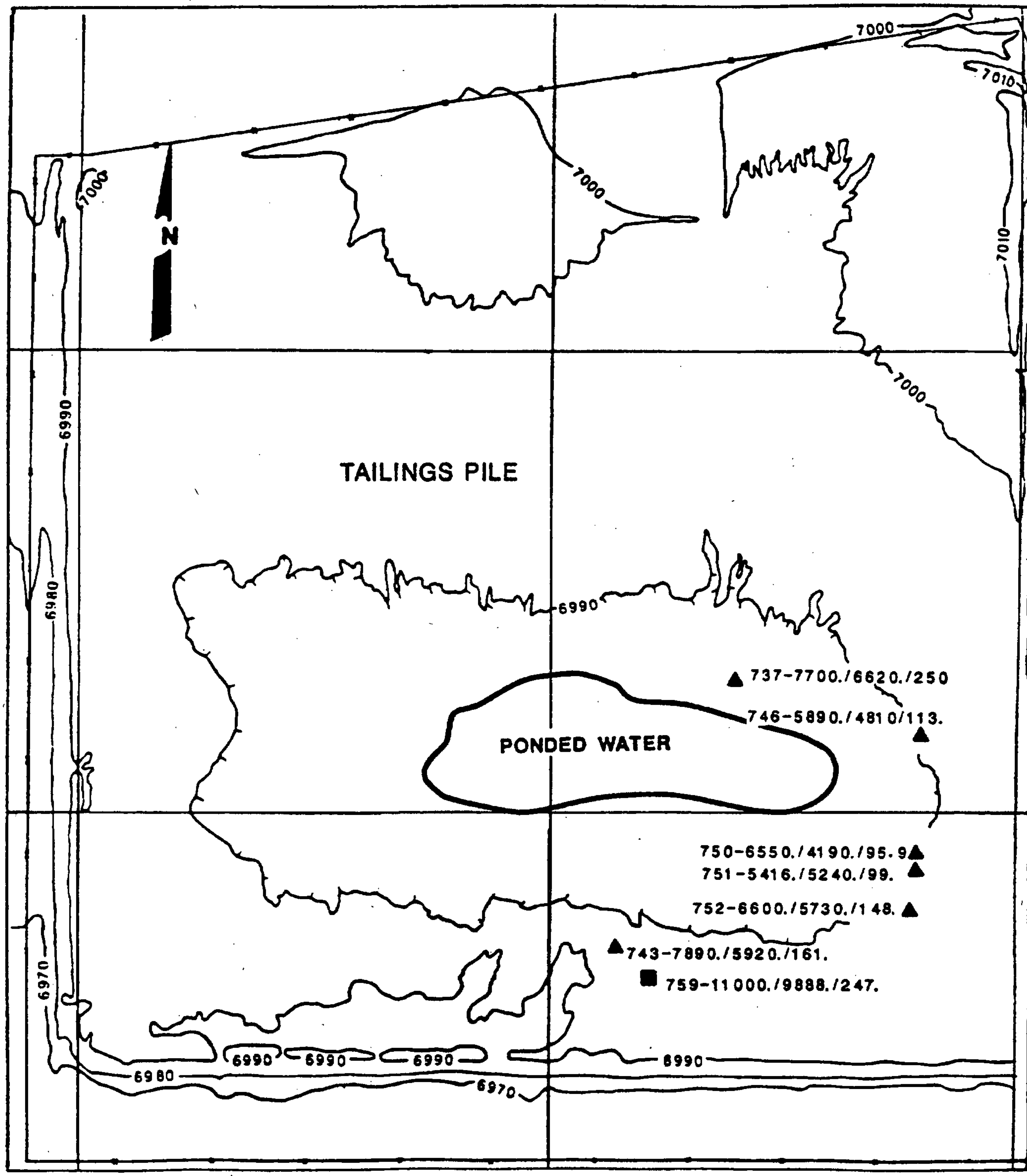


FIGURE D.8.19

AMBROSIA LAKE MILL SIMPLIFIED FLOW SHEET

D-247



■ 759 LYSIMETER LOCATION

▲ 737-7700./6620./250.

- PIEZOMETER (WELL POINT) LOCATION
- WELL POINT OR LYSIMETER NUMBER
- SULFATE CONCENTRATION (mg/l)
- SODIUM CONCENTRATION (mg/l)
- MOLYBDENUM CONCENTRATION (mg/l)

LEGEND

0 200 400 600 800

SCALE IN FEET

7000 SURFACE ELEVATION (FT. MSL)

FIGURE D.8.20 TAILINGS PORE WATER QUALITY

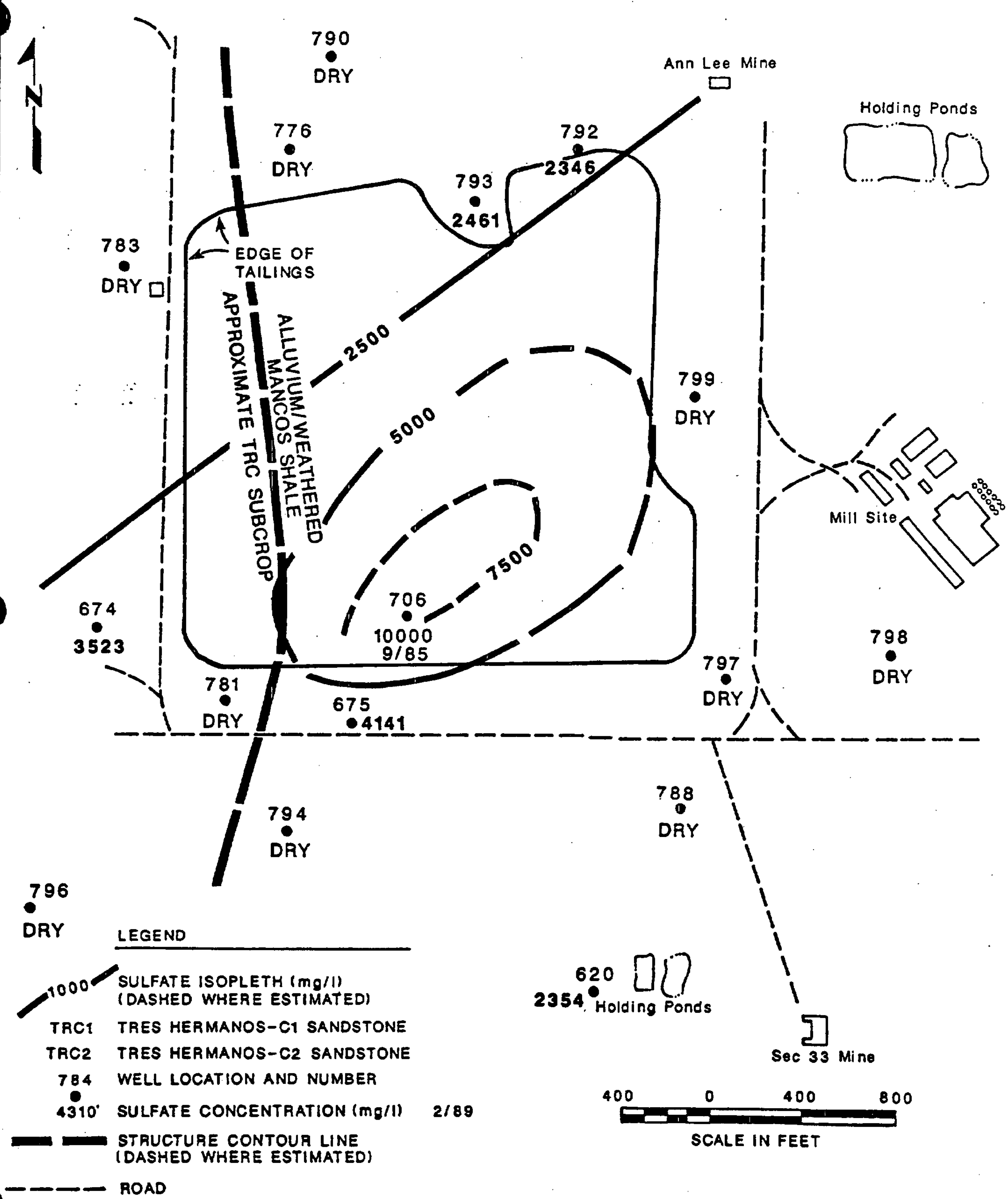


FIGURE D.8.21
SULFATE ISOPLETH MAP FOR GROUNDWATER IN ALLUVIUM/WEATHERED MANCOS SHALE AMBROSIA LAKE SITE, NEW MEXICO

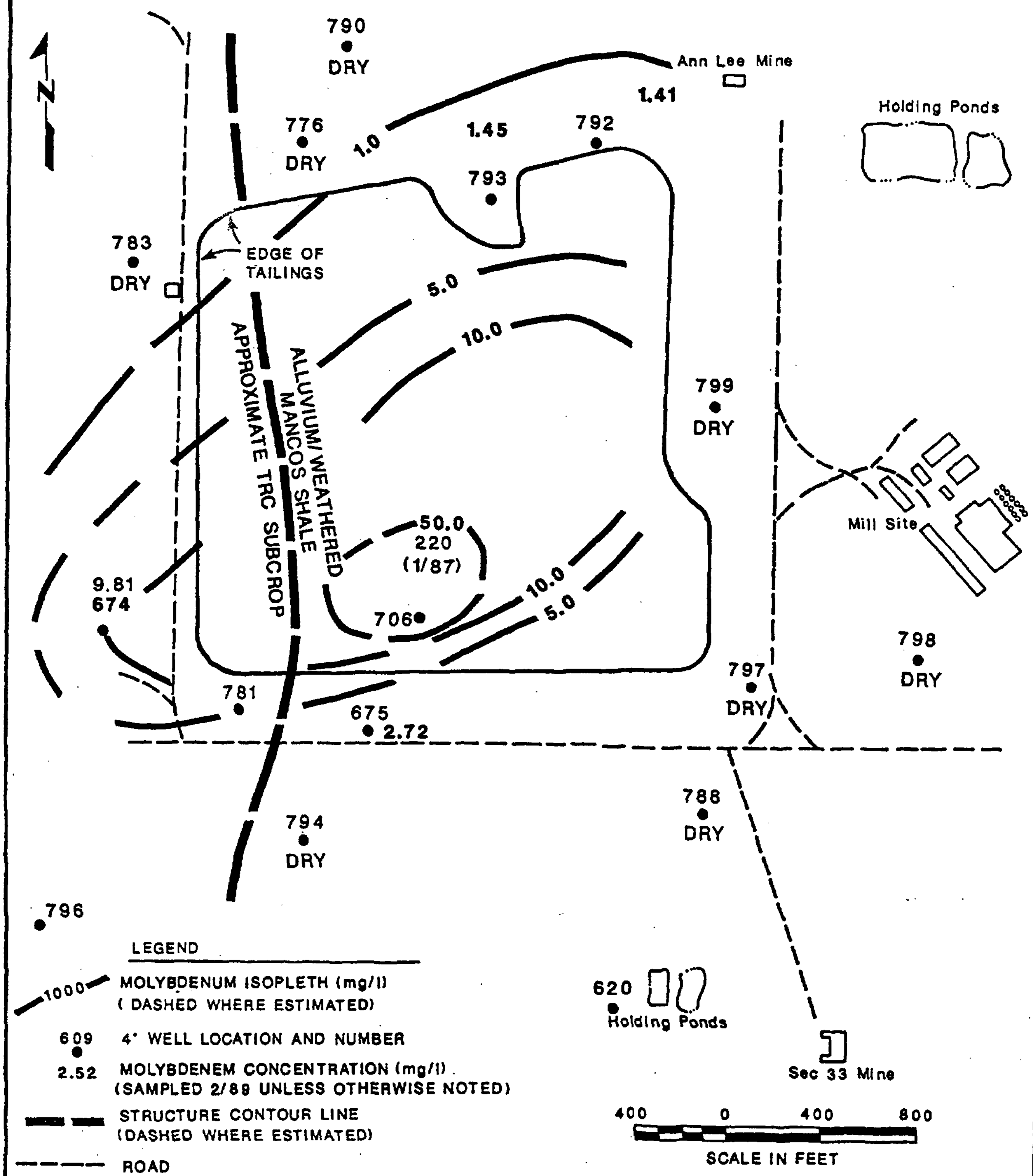


FIGURE D.8.22
MOLYBDENUM ISOPLETH MAP FOR GROUNDWATER IN ALLUVIUM/WEATHERED MANCOS SHALE AMBROSIA LAKE SITE, NEW MEXICO

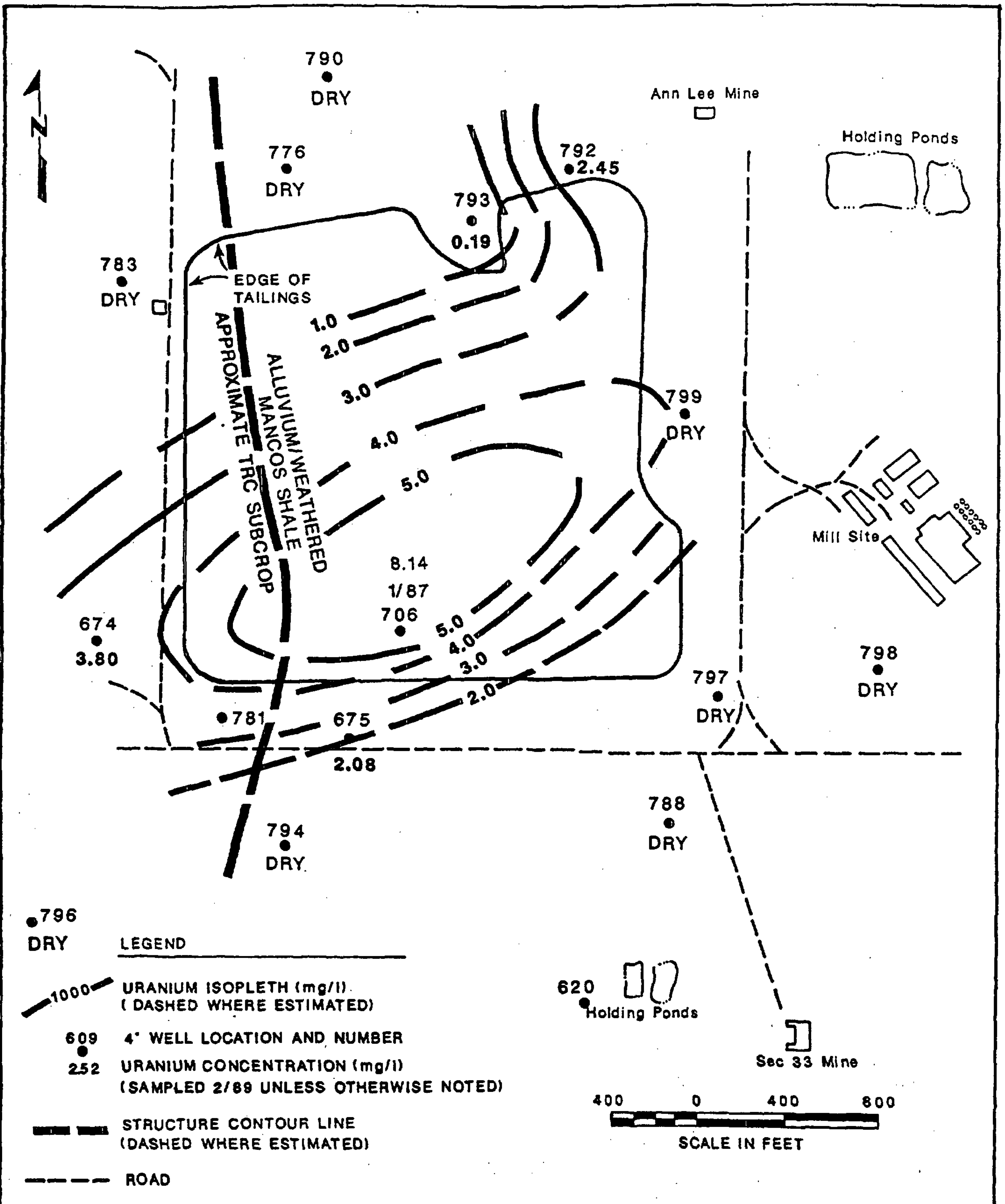


FIGURE D.8.23

URANIUM ISOPLETH MAP FOR GROUNDWATER IN ALLUVIUM/WEATHERED MANCOS SHALE AMBROSIA LAKE SITE, NEW MEXICO

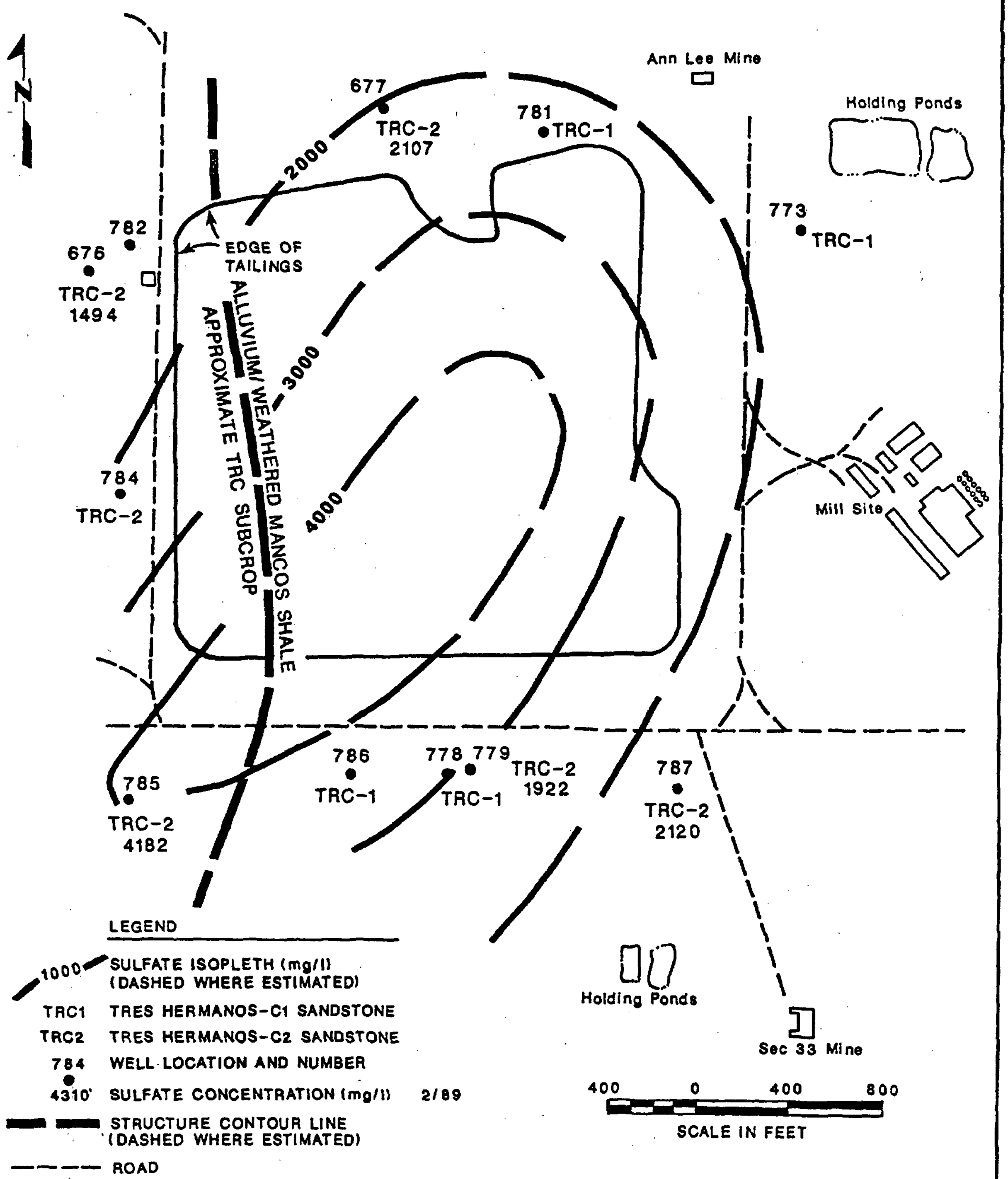


FIGURE D.8.24

SULFATE ISOPLETH MAP FOR GROUNDWATER IN THE TRES HERMANOS-C2 SANDSTONE AMBROSIA LAKE SITE, NEW MEXICO

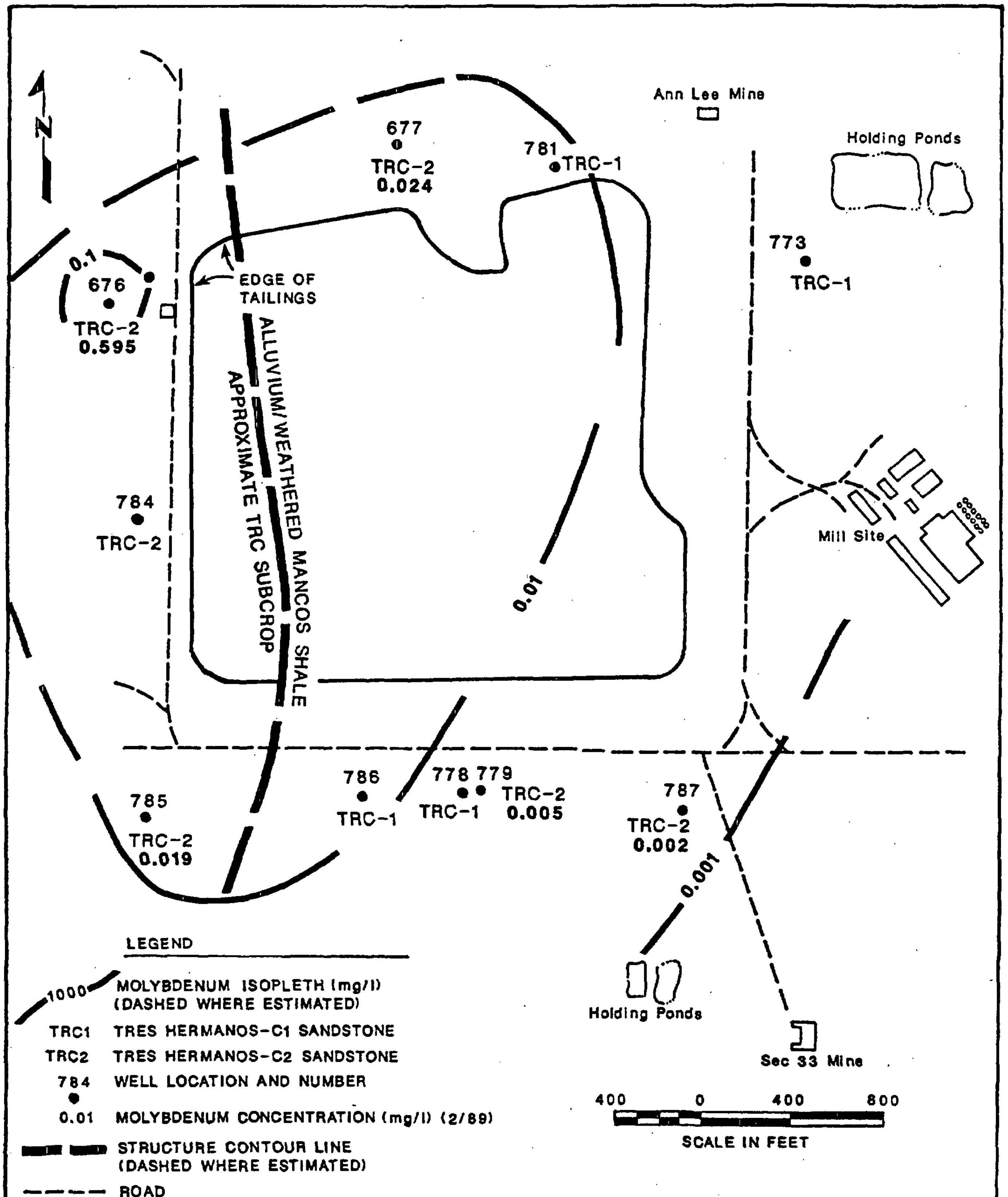


FIGURE D.8.25
MOLYBDENUM ISOPLETH MAP FOR GROUNDWATER IN THE TRES HERMANOS-C2 SANDSTONE AMBROSIA LAKE SITE, NEW MEXICO

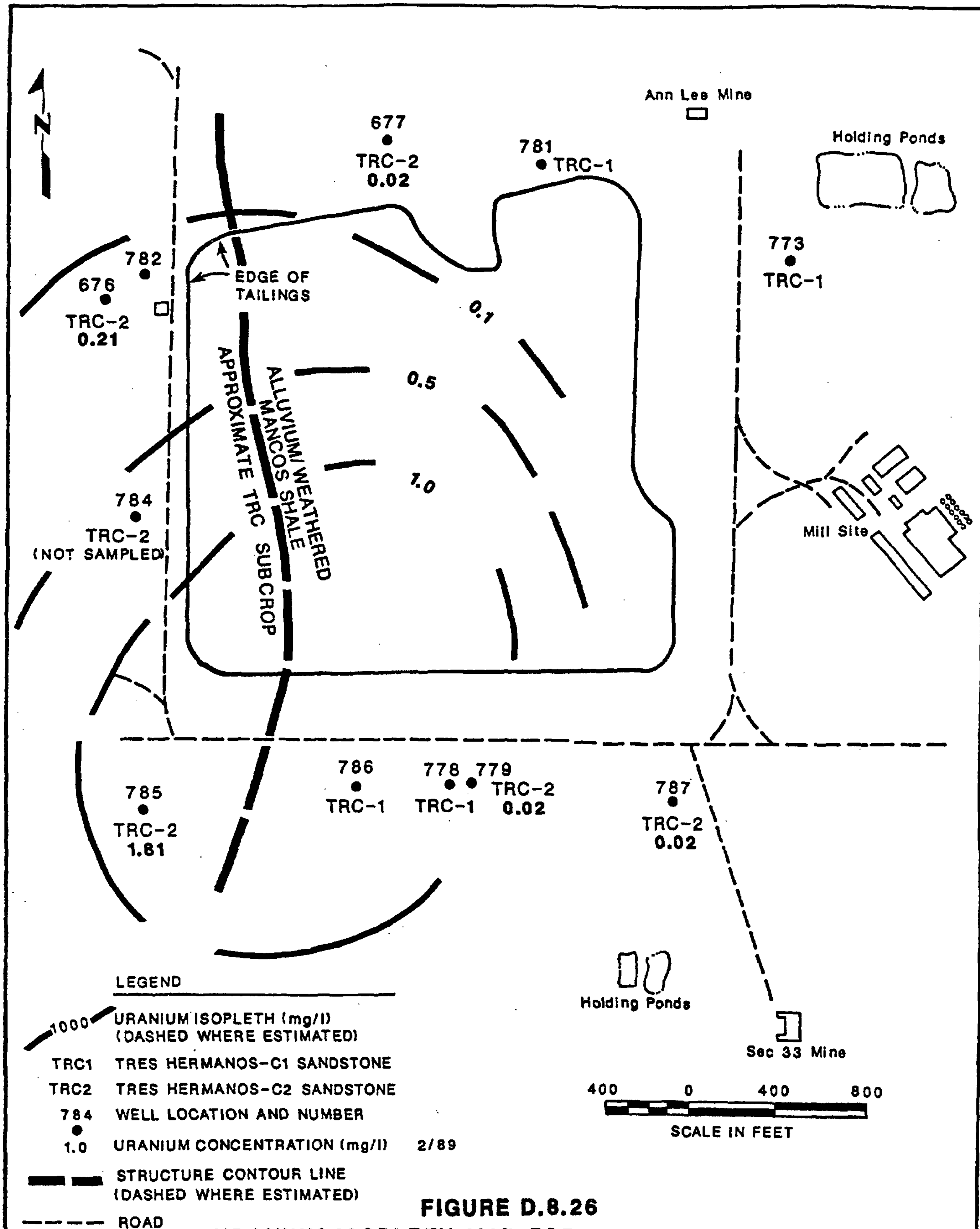


FIGURE D.8.26

URANIUM ISOPLETH MAP FOR GROUNDWATER IN THE TRES HERMANOS-C2 SANDSTONE AMBROSIA LAKE SITE, NEW MEXICO

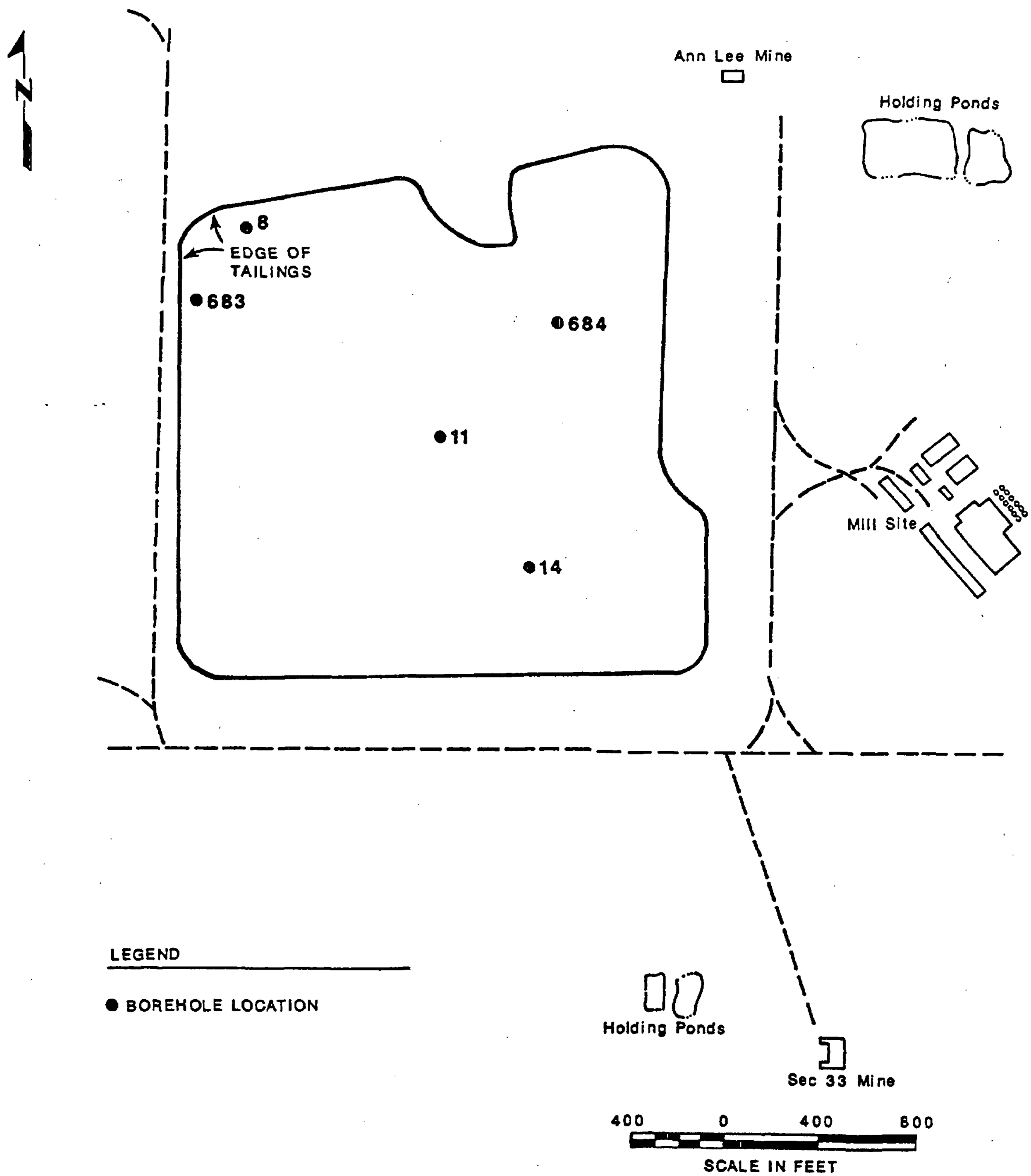


FIGURE D.8.27
LOCATIONS OF BOREHOLES
AMBROSIA LAKE SITE, NEW MEXICO

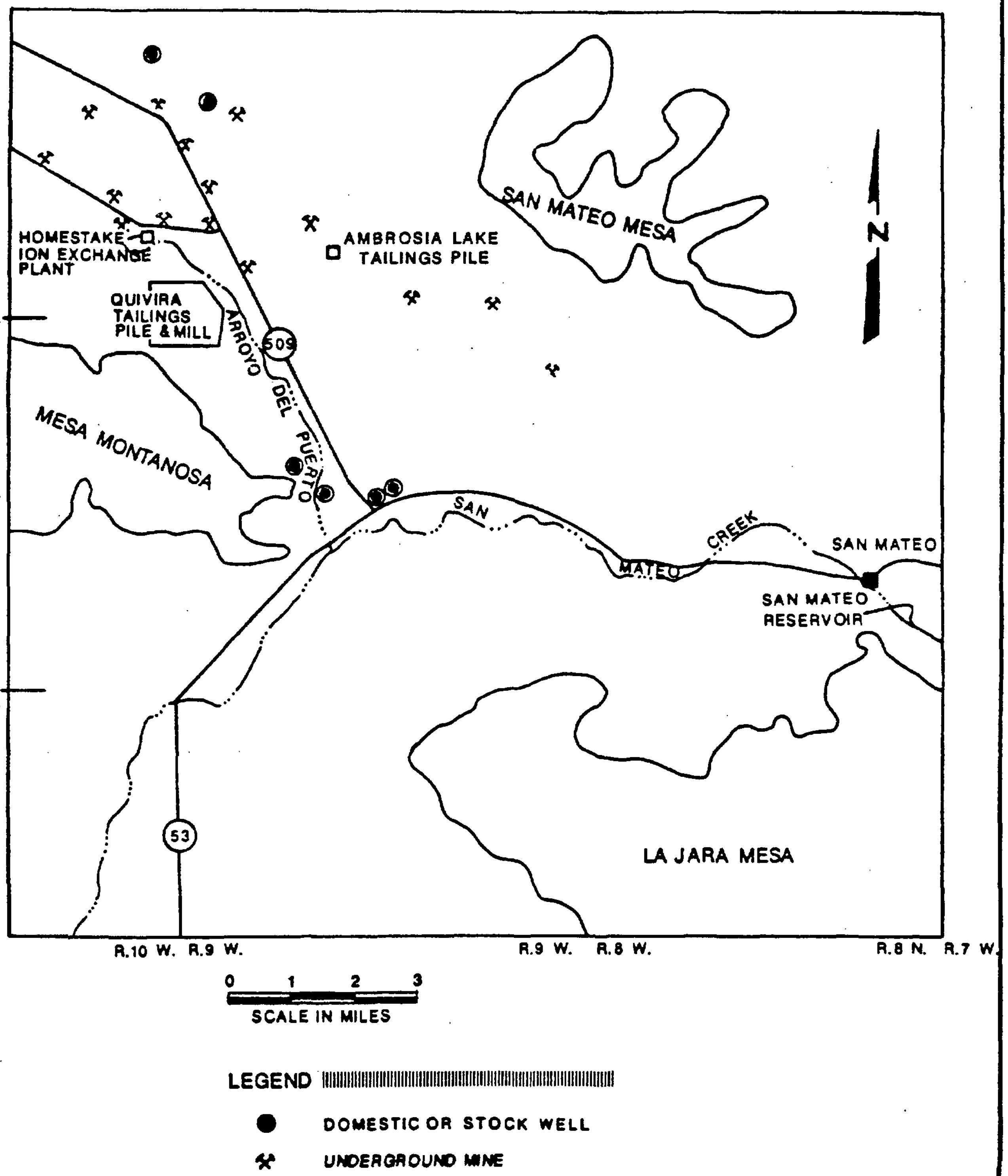


FIGURE D.8.28 LOCATIONS OF DOMESTIC AND STOCK WELLS IN THE AMBROSIA LAKE AREA

Table D.8.1 Ambrosia Lake site monitor well information

Well location number[a]	Well installer[b]	Well diameter (in)	Total depth (ft)	Ground surface elevation (ft MSL)	Top of casing (ft MSL)	Screened interval: Begin depth (ft from top of casing)	Screened interval: Length (ft)	Screened interval: Formation[c]
773	DOE	4.0	137.0	7006.2	7007.7	132.0	5.0	TrC1
774	DOE	4.0	255.0	7006.6	7007.4	250.0	5.0	TrB
775	DOE	4.0	95.0	6996.5	6998.7	90.0	5.0	TrC2
776	DOE	4.0	50.0	6997.0	6999.1	45.0	5.0	QAL
777	DOE	4.0	158.0	6961.3	6963.2	153.0	5.0	TrB
778	DOE	4.0	37.0	6961.2	6962.7	30.0	5.0	TrC1
779	DOE	4.0	62.0	6961.7	6964.0	57.0	5.0	TrC2
780	DOE	4.0	43.0	6966.0	6968.5	38.0	5.0	QAL/TrC2
781	DOE	4.0	40.0	6965.1	6968.4	35.0	5.0	QAL
782	DOE	4.0	70.0	6989.7	6991.8	65.0	5.0	TrC2
783	DOE	4.0	50.0	6990.7	6993.2	45.0	5.0	QAL
784	DOE	4.0	55.0	6974.8	6977.3	50.0	5.0	TrC2
785	DOE	4.0	45.0	6959.2	6961.3	40.0	5.0	TrC2
786	DOE	4.0	35.0	6961.5	6963.4	30.0	5.0	TrC1
787	DOE	4.0	80.0	6969.2	6971.3	75.0	5.0	TrC2
788	DOE	4.0	30.0	6967.5	6969.8	25.0	5.0	QAL
789	DOE	4.0	226.0	7001.8	7003.9	216.0	10.0	TrB
790	DOE	4.0	30.0	7002.9	7004.6	25.0	5.0	QAL
791	DOE	4.0	115.0	6998.8	7000.8	110.0	5.0	TrC1
792	DOE	4.0	20.0	6999.0	7001.1	15.0	5.0	QAL/weathered Kmc
793	DOE	4.0	28.0	6996.6	6998.6	23.0	5.0	QAL/weathered Kmc
794	DOE	4.0	22.0	6961.9	6964.2	17.0	5.0	QAL/weathered Kmc
796	DOE	4.0	23.0	6955.1	6957.3	18.0	5.0	QAL
797	DOE	4.0	21.5	6969.7	6972.0	16.5	5.0	QAL/weathered Kmc
798	DOE	4.0	20.0	6978.2	6980.4	15.0	5.0	QAL
799	DOE	4.0	12.0	6980.7	6892.8	7.0	5.0	QAL/weathered Kmc
674	DOE	4.0	49.0	6669.5	6972.9	36.5	10.0	QAL
675	DOE	4.0	35.0	6962.1	6966.0	32.5	10.0	QAL/weathered Kmc
676	DOE	4.0	120.0	6989.7	6991.8	97.5	20.0	TrC2
677	DOE	4.0	172.0	6999.2	7001.6	150.0	20.0	TrC2

Table D.8.1 Ambrosia Lake site monitor well information (Concluded)

Well location number[a]	Well installer[b]	Well diameter (in)	Total depth (ft)	Ground surface elevation (ft MSL)	Top of casing (ft MSL)	Screened interval: Begin depth (ft from top of casing)	Screened interval: Length (ft)	Screened interval: Formation[c]
678	DOE	4.0	262.0	6962.1	6963.2	240.0	20.0	TrB
679	DOE	4.0	362.0	6982.1	6983.6	340.0	20.0	TrA
680	DOE	4.0	350.0	6963.7	6965.7	310.0	20.0	Dakota
681	DOE	4.0	235.0	7000.7	7002.5	200.0	30.0	TrB
706[d]	SNL	4.0	45.0	6989.5	6990.45	35.0	10.0	QAL
620[a]	QMC	4.0	36.0	6951.9	6953.90	37.0	5.0	QAL

[a]Well locations plotted on Figure D.8.1.
[b]Well installer: DOE = wells installed for the U.S. Department of Energy by the Technical Assistance Contractor; SNL = Sandia National Laboratories; QMC = Quivira Mining Co.
[c]Formation: TrC1 = Tres Hermanos-C1; TrC2 = Tres Hermanos-C2; TrB = Tres Hermanos-B; TrA = Tres Hermanos-A; Kmc = Mancos Shale; QAL = Alluvium.
[d]Well locations plotted on Figure D.8.21.

Table D.8.2 Summary of lysimeters and well points

Well location number[a]	Formation sampled[b]	Hydraulic position
Lysimeter		
757	QAL/Kmc pore water	Source area
759	Tailings pore water	Source area
Well point		
737	Tailings water	Source area
743	Tailings water	Source area
746	Tailings water	Source area
747	QAL/Kmc water	Source area
748	QAL/Kmc water	Source area
749	QAL/Kmc water	Source area
750	Tailings water	Source area
751	Tailings water	Source area
752	Tailings water	Source area

[a]Well locations plotted in Figure D.8.14.

[b]QAL = alluvium; Kmc = Mancos Shale.

Table D.8.3 Water-level elevations in feet above sea level at the Ambrosia Lake site

Unit	Well no.	Casing elevation	October 1985 depth to water	October 1985 water-level elevation	May 1986 depth to water	May 1986 water-level elevation	April 1988 depth to water	April 1988 water-level elevation	July 1988 depth to water	July 1988 water-level elevation	February 1989 depth to water	February 1989 water-level elevation
			Date of measurement									
Alluvium and Weathered Mancos Shale												
	620	6953.9	31.8	6922.1					29.5	6924.4	29.8	6924.1
	674	6972.9									45.8	6927.1
	675	6966.0									22.2	6943.8
	792	7001.1	15.8	6985.3	17.2	6983.9	16.9	6984.2	16.9	6984.2	17.1	6984.0
	793	6998.6	21.4	6977.2	23.4	6975.2	22.5	6976.1	22.7	6975.9	22.9	6975.7
Tres Hermanos-C1 Sandstone												
	773	7007.7	132.1	6875.6	136.1	6871.6	Dry				137.4	6870.3
	778	6962.7	26.9	6935.8	28.0	6934.7	26.8	6935.9	26.8	6935.9	26.7	6936.0
	786	6963.4	21.5	6941.9	22.8	6940.6	21.7	6941.7	21.8	6941.6	21.8	6941.6
	791	7000.8	107.6	6893.2	104.2	6896.6	103.5	6897.3	101.5	6899.3	98.3	6902.5
Tres Hermanos-C2 Sandstone												
	676	6991.8									95.3	6896.5
	677	7001.6									87.9	6913.7
	779	6964.0	35.1	6928.9	39.2	6924.8	32.0	6932.0	30.9	6933.1	31.7	6932.3
	782	6991.8	60.6	6931.2	60.9	6930.9	59.5	6932.3	47.3	6944.5	59.7	6932.1
	784	6977.3	45.3	6932.0	48.1	6929.2	47.5	6929.8	59.5	6917.8	47.8	6929.5
	785	6961.3	41.8	6919.5	43.7	6917.6	41.1	6920.2	41.0	6929.3	41.5	6919.8
	787	6971.3	51.8	6916.5	61.6	6909.7	48.0	6923.3	51.6	6919.7	49.0	6922.3
Tres Hermanos-B Sandstone												
	777	6963.2	Dry				147.5	6815.7			147.4	6815.8
	678	6963.2									223.3	6739.9
	681	7002.5									212.7	6789.8
Tres Hermanos-A Sandstone												
	679	6983.6									346.6	6637.0
Dakota Sandstone												
	680	6965.7									317.1	6648.6

Table D.8.4 Slug test results from the Ambrosia Lake site monitor wells

	Hydraulic conductivity methods and results[a]					
Well location number[b]	Skibitzke (cm/s)	Ferris-Knowles[c] (cm/s)	Cooper-Papadopolous-Bredehoeft[c] (cm/s)	Bouwer-Rice (cm/s)	K ft/day	Geologic unit
Confined						
779	1.13×10^{-5}	Not valid	Not valid	N/A	0.032	TrC2[d]
787	2.08×10^{-5}	Not valid	Not valid	N/A	0.059	TrC2
791	1.46×10^{-5}	Not valid	Not valid	N/A	0.041	TrC1[e]
Semi-confined						
780	3.06×10^{-5}	3.86×10^{-5}	1.88×10^{-4}	7.31×10^{-5}	0.23[h]	QAL[f]/TrC2
Unconfined						
778	N/A	N/A	N/A	1.21×10^{-3}	3.4	TrC1
782	N/A	N/A	N/A	1.64×10^{-4}	0.46	TrC2
785	N/A	N/A	N/A	2.48×10^{-4}	0.70	TrC2
786	N/A	N/A	N/A	8.40×10^{-5}	0.24	TrC1
620	N/A	N/A	N/A	1.11×10^{-3}	3.1	QAL
674	N/A	N/A	N/A	1.90×10^{-5}	0.54	QAL
792	N/A	N/A	N/A	3.48×10^{-4}	0.99	QAL/weathered Kmc[g]
793	N/A	N/A	N/A	4.67×10^{-5}	0.13	QAL/weathered Kmc[g]

[a]N/A = method not applicable.
[b]Well locations plotted on Figure D.8.1.
[c]Not valid - data did not fit the assumptions of the method.
[d]TrC2 = Tres Hermanos-C2 Sandstone.
[e]TrC1 = Tres Hermanos-C1 Sandstone.
[f]QAL = alluvium.
[g]Kmc = Mancos Shale.
[h]averaged value.

Table D.8.5 Hydraulic conductivities reported for the alluvium and Tres Hermanos-B Sandstone in Ambrosia Lake Valley

Unit	Hydraulic conductivity	Method and reference
Alluvium	2×10^{-4} to 5×10^{-4} cm/s	Two pumping tests by Quivira Mining Co., 1980 (Ganus, 1980)
Alluvium	2×10^{-5} cm/s	Pumping test in monitor well H-9 (FBD, 1983)
Alluvium	1.0×10^{-3} to 5.0×10^{-3} cm/s	Falling head permeability tests (Thomson and Heggen, 1981)
Tres Hermanos-B Sandstone	1×10^{-4} to 1×10^{-3} cm/s	In situ single packer permeability tests by Woodward-Clyde Consultants for Quivira (W-C, 1983)
Tres Hermanos-B Sandstone/ Mancos Shale	2×10^{-5} cm/s	In situ permeability tests by Woodward-Clyde Consultants for Quivira (W-C, 1983)
Mancos Shale (weathered)	1.4×10^{-7} to 1.4×10^{-6} cm/s	Measured by Gulf Corp in their San Mateo mine in T14N R8W (Brod and Stone, 1981)
Mancos Shale	4.33×10^{-8} cm/s	Grinding then estimated from a consolidation test (Thomson and Heggen, 1981)

Table D.8.6 Average linear groundwater velocities for Ambrosia Lake site

Stratigraphic unit	Parameter	Velocity Minimum	Velocity Maximum	Velocity Average
Alluvium/weathered Mancos Shale	Inputs:			
	Hydraulic conductivity (K)(cm/s)	4.67×10^{-5}	1.11×10^{-3}	3.48×10^{-4}
	Hydraulic gradient (i)	0.017	0.033	0.025
	Effective porosity (n_e)	0.16	0.10	0.13
	Average linear velocity ($v = \frac{Ki}{N_e}$)(cm/s)	4.96×10^{-6}	3.66×10^{-4}	6.69×10^{-5}
Tres Hermanos-C1 Sandstone Member	Inputs:			
	Hydraulic conductivity (K)(cm/s)	1.46×10^{-5}	1.21×10^{-3}	4.24×10^{-4}
	Hydraulic gradient (i)	0.019	0.033	0.026
	Effective porosity (n_e)	0.06	0.04	0.05[a]
	Average linear velocity ($v = \frac{Ki}{N_e}$)(cm/s)	4.62×10^{-6}	9.98×10^{-4}	2.21×10^{-4}
Tres Hermanos-C2 Sandstone Member	Inputs:			
	Hydraulic conductivity (K)(cm/s)	1.13×10^{-5}	2.48×10^{-4}	1.09×10^{-4}
	Hydraulic gradient (i)	0.014	0.033	0.024
	Effective porosity (n_e)	0.06	0.04	0.05[a]
	Average linear velocity ($v = \frac{Ki}{N_e}$)(cm/s)	2.64×10^{-6}	2.05×10^{-4}	5.23×10^{-5}
Westwater Canyon Member	Inputs:			
	Hydraulic conductivity (K)(cm/s)[a]	3.81×10^{-4}	4.70×10^{-4}	4.31×10^{-4}
	Hydraulic gradient (i)	0.019[b]	0.033[b]	0.026[b]
	Effective porosity (n_e)	0.12	0.08	0.10[a]
	Average linear velocity ($v = \frac{Ki}{N_e}$)(cm/s)	6.03×10^{-5}	1.94×10^{-4}	1.14×10^{-4}

[a]Ref. Brod, 1979.
[b]Assumed to be similar to the Tres Hermanos-C1 and -C2 Sandstone Members as the dip of the geologic units is identical and the hydraulic conductivities are similar.

Table D.8.7 Calculated drawdown in alluvium/weathered Mancos Shale at the Ambrosia Lake site for different transmissivity values[a]

Transmissivity (gpd/ft^2)	Pumping duration		
	1 day	10 days	100 days
13	11.82 ft	13.94 ft	16.05 ft
15	10.36 ft	12.19 ft	14.02 ft
18	8.75 ft	10.28 ft	11.81 ft

[a]Distance from pumping well = 0.1 ft. Storage coefficient based on actual pump test data = 0.001. Calculated drawdown based on the Theis equation (Freeze and Cherry, 1979).

Table D.8.8 United Nuclear Corporation and Quivira Mine Company mine water discharge quality

Constituent	Unit of measurement	United Nuclear Corporation (Sample Dates) 10/27/77	11/17/78	11/07/79	Ann Lee Mine 06/21/82	Quivira Section 30 W. Mine 05/13/83
Aluminum	mg/l	--	--	<0.250	<0.100	0.37
Ammonia	mg/l	0.015	0	0.05	--	--
Arsenic	mg/l	<0.005	<0.005	0.009	0.006	0.27
Barium	mg/l	0.27	0.074	<0.100	<0.100	<0.02
Bicarbonate	mg/l	--	228	174.0	317	730
Cadmium	mg/l	<0.001	<0.001	--	<0.01	0.024
Calcium	mg/l	--	150	194	265	720
Chloride	mg/l	108	97.5	188	210	470
Chromium	mg/l	--	--	--	<0.100	0.078
Cobalt	mg/l	--	--	--	--	0.059
Copper	mg/l	--	--	--	<0.025	0.066
Conductivity	micromhos	2657	2241	3288	3250	--
Iron	mg/l	--	--	--	0.23	0.21
Lead	mg/l	--	<0.005	<0.005	<0.010	0.48
Magnesium	mg/l	--	--	45.3	43	410
Manganese	mg/l	--	--	--	--	7.2
Mercury	mg/l	--	--	--	<0.002	--
Molybdenum	mg/l	3.20	1.914	3.05	1.8	0.076
Nickel	mg/l	--	--	--	--	0.140
Nitrate (as N)	mg/l	0.11	<0.01	--	<1.00	<1.00
pH	standard	8.08	--	8.12	6.77	6.90
Potassium	mg/l	--	8.19	9.75	11	10
Selenium	mg/l	0.268	0.171	0.122	0.13	0.30
Silver	mg/l	--	--	--	0.008	0.099
Sodium	mg/l	428	421	511	510	410
Sulfate	mg/l	1060	1115	1280	1460	2910
Total suspended solids	mg/l	1.1	1.0	2.0	--	--
Total dissolved solids	mg/l	1852	1903	2441	2660	5220
Vanadium	mg/l	--	<0.010	<0.010	0.010	--
Zinc	mg/l	--	<0.100	<0.250	--	0.22
Gross alpha	pCi/l	--	0	0	--	--
Radium-226	pCi/l	29±1	65±1	19±6	23	2.5
Radium-228	pCi/l	0±2	--	--	0	2.5
Lead-210	pCi/l	17±6	--	--	0	--
Uranium	mg/l	0.32	2.23	1.31	5.1	--

Ref. NMEID, 1983, 1980.

Note: -- means not analyzed.

Table D.8.9 Composition of mill effluent at the Ambrosia Lake tailings pond

Constituent[a]	Unit of measurement	Concentration
Sodium sulfate	mg/l	10,000
Sodium carbonate	mg/l	5,000
Uranium	mg/l	5
Vanadium	mg/l	114
Molybdenum	mg/l	178
Silicon dioxide	mg/l	228
Percent solids		45
Percent liquid		55

[a]Small amounts of chloride, selenium, fluoride, and phosphate also present.

Ref. Hunter, 1958.

Table D.8.10 Chemical composition of alkaline leach mill effluents

		Mill	
Constituents	Unit of measurement[a]	United Nuclear-Homestake Partners (Milan, New Mexico)	An alkaline leach mill in New Mexico (median from 3 samples)
Total suspended solids	mg/l	52.0	--
Total dissolved solids	mg/l	20,710	20,700
Conductivity	(micromhos)	23,990	--
pH	standard	10.2	10.2
Arsenic	mg/l	7.19	5.0
Barium	mg/l	0.051	--
Selenium	mg/l	31.16	31.0
Molybdenum	mg/l	105	104
Ammonia	mg/l	13.9	--
Sodium	mg/l	8,464	8,460
Chloride	mg/l	1,014	1,010
Sulfate	mg/l	8,346	8,350
Calcium	mg/l	10.0	--
Potassium	mg/l	31.2	--
Bicarbonate	mg/l	--	--
Cadmium	mg/l	0.028	--
Nitrate (as N)	mg/l	22.42	--
Magnesium	mg/l	--	--
Vanadium	mg/l	13.6	--
Zinc	mg/l	<0.10	--
Aluminum	mg/l	--	--
Lead	mg/l	<0.005	--
Gross alpha	pCi/l	10,000 ± 1,000	6,700
Radium	pCi/l	90 ± 1	58 ± 4
Lead	pCi/l	49 ± 8	--
Uranium	mg/l	52.8	44

[a]pCi/l - picocuries per liter ± one standard deviation.

Ref. NMEID, 1980; Gallagher and Gord, 1981; presumably the United Nuclear Homestake Partners mill, although not stated.

Table D.8.11 Maximum observed concentrations of EPA MCL constituents in lysimeter and well points at the Ambrosia Lake, New Mexico, site -- tailings and unsaturated alluvium beneath tailings[a]

Constituent	MCL (mg/l)	Lysimeters and well points									
		743	746	747	748	749	750	751	752	757	759
Arsenic	0.05	0.005	0.005	0.005	0.005	0.005	0.30	0.10	0.11	0.01	0.17
Barium	1.0	NA	0.30	0.1	NA	NA	0.10	0.10	0.10	0.1	0.10
Cadmium	0.01	0.0005	0.0005	0.0005	0.0005	0.0005	0.0070	0.0060	0.0060	0.005	0.008
Chromium	0.05	0.10	0.03	0.04	0.05	0.05	0.09[b]	0.11[b]	0.04	0.02	0.11[b]
Lead	0.05	NA	0.0005	0.0005	NA	NA	0.74	0.02	0.03	0.005	0.02
Mercury	0.05	NA	0.0001	0.0001	NA	NA	0.0001	0.0001	0.0001	NA	NA
Molybdenum	0.1	161.0[b]	113.0[b]	48.7[b]	29.0[b]	66.0[b]	120.0[b]	118.0[b]	148.0[b]	158.0[b]	247.0[b]
Nitrate	44.0	6.0	3.0	3.0	2.0	1.0	1.0	3600.0[b]	3.0[b]	150.0[b]	NA
Selenium	0.01	0.0025	0.0025	0.0025	0.0025	0.0025	0.320	0.294	0.371	0.016[b]	0.403[b]
Silver	0.05	NA	0.005	0.005	NA	NA	0.01	0.02	0.005	0.005	0.02
Uranium	0.044	2.17[b]	1.32[b]	1.24[b]	5.84[b]	5.76[b]	8.4[b]	14.6[b]	8.65[b]	14.7[b]	12.6[b]
Gross alpha	5 pCi/l	NA	NA	NA	NA	NA	NA	NA	0	NA	NA
Radium-226 and -228	15 pCi/l	NA	140.0[b]	190.0[b]	113.0[b]	117.0[b]	90.1[b]	220.0[b]	22.1[b]	NA	NA

[a]NA = Not analyzed.
[b]Exceeds MCL in proposed EPA standard.

Table D.8.12 Maximum observed concentrations of EPA MCL constituents in monitor wells at the Ambrosia Lake, New Mexico, site -- alluvium/weathered Mancos Shale[a]

		Monitor wells						
Constituent	MCL (mg/l)	706	620	674	675	780	792	793
Arsenic	0.005	0.2720[b]	0.01	0.0005	0.0005	0.005	0.016	0.16
Barium	1.0	NA	0.10	0.005	0.02	0.05	0.05	0.05
Cadmium	0.01	NA	0.0005	0.0005	0.0003	0.0005	0.005	0.005
Chromium	0.05	0.02	0.16[b]	0.005	0.005	0.02	0.28[b]	0.28[b]
Lead	0.05	NA	0.005	0.001	0.001	0.005	0.01	0.01
Mercury	0.05	NA	0.0001	0.0001	0.0001	0.0001	0.0007	0.0003
Molybdenum	0.1	220.0[b]	0.5[b]	9.81[b]	2.72[b]	3.6[b]	1.87[b]	2.01[b]
Nitrate	44.0	25.0	13.6	40.0	145.0[b]	140.0[b]	1.8	252.0[b]
Selenium	0.01	0.012[b]	0.07[b]	1.39[b]	0.51[b]	0.54[b]	1.8[b]	1.1[b]
Silver	0.05	0.02	0.04	0.005	0.005	0.005	0.11[b]	0.11[b]
Uranium	0.044	1.11[b]	7.88[b]	3.80[b]	2.08[b]	3.47[b]	3.31[b]	0.39[b]
Gross alpha	5 pCi/l		0	0	0	0	285.54	48.44
Radium-226 and -228	15 pCi/l	131.8[b]	10.03[b]	0.744	2.52	3.10	6.90	1.56

[a]NA = Not analyzed.
[b]Exceeds MCL in proposed EPA standard.

Table D.8.13 Maximum observed concentrations of EPA MCL constituents in monitor wells at the Ambrosia Lake, New Mexico, site -- Tres Hermanos-C1 Sandstone Member[a]

Constituent	MCL (mg/l)	Monitor wells 773	778	786	791
Arsenic	0.05	0.005	0.022	0.01	0.02
Barium	1.0	NA	0.05	0.22	0.10
Cadmium	0.01	0.0005	0.014[b]	0.001	0.0005
Chromium	0.05	0.05	0.22[b]	0.14[b]	0.21[b]
Lead	0.05	NA	0.01	0.005	0.005
Mercury	0.05	NA	0.0005	0.0003	0.0001
Molybdenum	0.1	0.320[b]	0.160[b]	0.212[b]	0.210[b]
Nitrate	44.0	2.0	430.0[b]	53.0[b]	8.0
Selenium	0.01	0.0025	0.280[b]	0.764[b]	0.16[b]
Silver	0.05	NA	0.06[b]	0.02	0.005
Uranium	0.044	0.0001	11.8[b]	1.73[b]	0.0007
Gross alpha	5 pCi/l	NA	3422.85	218.78[b]	NA
Radium-226 and -228	15 pCi/l	22.0[b]	8.81[b]	21.3[b]	1.5

[a]NA = Not analyzed.
[b]Exceeds MCL in proposed EPA standard.

Table D.8.14 *Maximum observed concentrations of EPA MCL constituents in monitor wells at the* Ambrosia Lake, New Mexico, site -- Tres Hermanos-C2 Sandstone Member[a]

Constituent	MCL (mg/l)	Monitor wells 676	677	779	782	784	785	787
Arsenic	0.05	0.0005	0.0005	0.005	0.005	0.005	0.026	0.019
Barium	1.0	0.02	0.02	0.30	0.30	NA	0.10	0.05
Cadmium	0.01	0.0001	0.0009	0.0005	0.0005	0.0005	0.0090	0.0070
Chromium	0.05	0.005	0.005	0.04	0.04	0.11[b]	0.24[b]	0.23[b]
Lead	0.05	0.0005	0.0005	0.005	0.005	NA	0.01	0.01
Mercury	0.05	0.0001	0.0001	0.0001	0.0001	NA	0.0006	0.0004
Molybdenum	0.1	0.595[b]	0.024[b]	0.14[b]	0.16[b]	0.19[b]	0.35[b]	0.25[b]
Nitrate	44.0	4.75	5.10	2.00	4.00	5.00	20.00	38.90
Selenium	0.01	0.091[b]	0.006	0.0025	0.0025	0.007	0.324[b]	0.54[b]
Silver	0.05	0.005	0.005	0.005	0.005	NA	0.080[b]	0.090[b]
Uranium	0.044	0.207[b]	0.016	0.024	0.0031	0.0001	3.30	0.018
Gross alpha	5 pCi/l	0.00	0.00	64.26	NA	NA	646.03[b]	20.66[b]
Radium-226 and -228	15 pCi/l	2.48	1.87	5.60	2.80	0.80	11.56	3.06

[a]NA = Not analyzed.
[b]Exceeds MCL in proposed EPA standard.

Table D.8.15 Maximum observed concentrations of EPA MCL constituents in monitor wells at the Ambrosia Lake, New Mexico, site -- Tres Hermanos-B Sandstone Member

		Monitor wells		
Constituent	MCL (mg/l)	678	681	777
Arsenic	0.05	0.001	0.003	0.012
Barium	1.0	0.02	0.02	0.03
Cadmium	0.01	0.0006	0.0001	0.006
Chromium	0.05	0.005	0.005	0.04
Lead	0.05	0.0005	0.0005	0.01
Mercury	0.05	0.0001	0.0001	0.0001
Molybdenum	0.1	0.016	0.003	0.100
Nitrate	44.0	250.0[a]	1.32	2.11
Selenium	0.01	0.011[a]	0.001	0.047[a]
Silver	0.05	0.005	0.005	0.01
Uranium	0.044	0.029	0.01	0.009
Gross alpha	5 pCi/l	0	0	0
Radium-226 and -228	15 pCi/l	1.71	0.65	1.20

[a]Exceeds MCL in proposed EPA standard.

Table D.8.16 Maximum observed concentrations of Appendix I inorganic constituents in monitor wells at the Ambrosia Lake, New Mexico, site -- tailings and unsaturated alluvium beneath the tailings[a]

		Monitor wells									
Constituent[b]	Detection Limits	743	746	747	748	749	750	751	752	757	759
Antimony	0.003	NA	0.0015	0.0015	NA	NA	0.098	0.07	0.088	0.0015	0.083
Beryllium	0.010	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon disulphide	0.005	NA	NA	NA	NA	NA	NA	<0.005	NA	NA	NA
Cobalt	0.050	0.10	0.08	0.09	0.12	0.11	0.07	0.07	0.07	0.10	0.05
Copper	0.020	NA	0.04	0.05	NA	NA	0.08	0.08	0.04	0.03	0.09
Cyanide	0.010	NA	0.005	0.05	NA	NA	0.005	0.005	0.005	0.005	0.005
Fluorine	0.100	19.0	19.0	2.8	NA	NA	21.0	14.0	16.0	NA	NA
Nickel	0.040	NA	0.14	0.14	NA	NA	0.13	0.144	0.13	NA	0.02
Sulphide	0.100	NA	0.05	0.05	NA	NA	0.05	0.05	0.05	0.05	0.05
Thallium	0.100	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tin	0.005	NA	0.0025	0.0025	NA	NA	0.398	0.338	0.323	0.0025	0.40
Vanadium	0.010	0.56	0.09	0.005	0.54	0.55	0.005	0.005	0.005	0.45	0.005
Zinc	0.005	NA	0.04	1.73	NA	NA	0.53	0.326	0.780	0.01	0.025

[a]NA = not analyzed.
[b]all constituents measured in mg/l.

Table D.8.17 Maximum observed concentrations of Appendix I inorganic constituents in monitor wells at the Ambrosia Lake, New Mexico, site -- alluvium/weathered Mancos Shale[a]

Constituent[b]	Detection Limits	Monitor wells						
		706	620	674	675	780	792	793
Antimony	0.003	NA	0.013	0.003	0.003	0.0015	0.013	0.014
Beryllium	0.010	NA	0.0025	0.0025	0.0025	NA	0.0025	0.0025
Carbon disulphide	0.005	NA	<0.005	NA	NA	NA	NA	<0.005
Cobalt	0.050	0.10	0.06	0.005	0.005	0.24	0.12	0.13
Copper	0.020	0.007	0.03	0.005	0.005	0.03	0.06	0.06
Cyanide	0.010	NA	0.005	0.004	0.263	0.0005	0.001	0.001
Fluorine	0.100	14.5	0.80	0.60	0.30	2.20	1.10	2.80
Nickel	0.040	NA	0.06	0.01	0.01	0.10	0.13	0.14
Sulphide	0.100	NA	0.05	0.005	0.01	0.05	0.05	0.05
Thallium	0.100	NA	0.0005	0.0005	0.005	NA	0.005	0.002
Tin	0.005	NA	0.01	0.0005	0.0005	0.0025	0.029	0.026
Vanadium	0.010	0.390	0.070	0.005	0.005	0.50	0.26	0.39
Zinc	0.005	NA	0.017	0.580	0.960	0.980	0.070	0.068

[a]NA = not analyzed.
[b]all constituents measured in mg/l.

Table D.8.18 Maximum observed concentrations of Appendix I inorganic constituents in monitor wells at the Ambrosia Lake, New Mexico, site--Tres Hermanos-C1 Sandstone[a]

		Monitor wells			
Constituent[b]	Detection Limits	773	778	786	791
Antimony	0.003	NA	0.022	0.0018	0.0015
Beryllium	0.010	NA	0.0025	0.0025	NA
Carbon disulphide	0.005	NA	NA	NA	NA
Cobalt	0.050	0.07	0.08	0.09	0.06
Copper	0.020	NA	0.050	0.036	0.010
Cyanide	0.010	NA	0.103	0.493	0.005
Fluorine	0.100	1.10	0.60	2.20	1.10
Nickel	0.040	NA	0.08	0.08	0.07
Sulphide	0.100	NA	0.05	0.05	0.05
Thallium	0.100	NA	NA	0.002	0.0005
Tin	0.005	NA	0.030	0.013	0.0025
Vanadium	0.010	0.21	0.23	0.42	0.030
Zinc	0.005	NA	0.039	0.166	0.0025

[a]NA = not analyzed.
[b]all constituents measured in mg/l.

Table D.8.19 Maximum observed concentrations of Appendix I inorganic constituents in monitor wells at the Ambrosia Lake, New Mexico, site -- Tres Hermanos-C2 Sandstone[a]

Constituent[b]	Detection limits	Monitor wells						
		676	677	779	782	784	785	787
Antimony	0.003	0.009	0.004	0.0015	0.0015	NA	0.043	0.025
Beryllium	0.010	0.0025	0.0025	NA	NA	NA	0.0025	0.0025
Carbon disulphide	0.005	NA	NA	NA	NA	NA	NA	NA
Cobalt	0.050	0.005	0.005	0.10	0.025	0.025	0.10	0.005
Copper	0.020	0.01	0.005	0.03	0.02	NA	0.05	0.040
Cyanide	0.010	0.001	0.001	0.005	0.005	NA	0.350	0.005
Fluorine	0.100	1.10	1.0	0.5	0.90	0.80	1.4	0.5
Nickel	0.040	0.01	0.01	0.14	0.06	NA	0.15	0.13
Sulphide	0.100	0.01	0.005	0.05	0.05	NA	0.05	0.05
Thallium	0.100	0.005	0.005	NA	NA	NA	0.003	0.0005
Tin	0.005	0.0005	0.006	0.0025	0.0025	NA	0.03	0.031
Vanadium	0.010	0.005	0.005	0.34	0.005	0.38	0.40	0.29
Zinc	0.005	0.005	0.02	0.74	0.0025	NA	0.315	0.061

[a]NA = not analyzed.
[b]all constituents measured in mg/l.

Table D.8.20 Maximum observed concentrations of Appendix I inorganic constituents in monitor wells at the Ambrosia Lake, New Mexico, site -- Tres Hermanos-B Sandstone[a]

		Monitor wells		
Constituent[b]	Detection limits	678	681	777
Antimony	0.003	0.005	0.019	0.009
Beryllium	0.010	0.0025	0.0025	0.0025
Carbon disulphide	0.005	NA	NA	NA
Cobalt	0.050	0.01	0.005	0.01
Copper	0.020	0.01	0.01	0.02
Cyanide	0.010	0.001	0.001	0.004
Fluorine	0.100	0.01	0.90	0.95
Nickel	0.040	0.04	0.01	0.02
Sulphide	0.100	0.005	0.005	0.050
Thallium	0.100	0.0005	0.0005	0.0005
Tin	0.005	0.0005	0.0005	0.370
Vanadium	0.010	0.005	0.005	0.06
Zinc	0.005	0.02	0.005	0.005

[a]NA = not analyzed.
[b]All constituents measured in mg/l.

Table D.8.21 Profiles of pH as a function of depth beneath tailings[a]

Borehole #8			Borehole #11			Borehole #14		
Sample Depth			Sample Depth			Sample Depth		
Top (cm)	Base (cm)	pH	Top (cm)	Base (cm)	pH	Top (cm)	Base (cm)	pH
1	10	9.60	1	10	8.70	1	10	10.10
10	20	9.50	10	20	9.50	10	20	10.20
40	50	9.70	40	50	10.00	100	150	10.20
90	100	9.20	140	150	9.90	150	200	10.20
190	200	10.10	290	300	9.40	230	250	10.30
240	250[b]	10.30	350	360	10.10	380	400	10.40
290	300	10.30	360	370[b]	9.60	480	500	10.10
340	350	10.30	370	385	9.90	570	580	10.20
440	450	10.40	385	400	10.00	580	590[b]	9.80
590	600	8.50	440	450	8.60	590	600	10.40
			740	750	8.50	600	625	10.30
						625	650	10.40
						675	700	10.40

[a]Sample locations are shown on Figure D.8.
[b]Tailings/subsoil interface.

Table D.8.22 Summary of Eh and pH conditions at Ambrosia Lake tailings site, New Mexico

Formation	Eh	pH
Tailings pore fluid	+0.120	8.16
Alluvium/weathered Mancos Shale	+0.117	7.31
Tres Hermanos-C Sandstone	+0.071	7.14
Westwater Canyon Member[a]	+0.200	7.47

[a]Longmire, 1984

Table D.8.23 Distributions of species of selected hazardous constituents at Ambrosia Lake site, New Mexico

Species	Tailings pore fluid form (concentration)[a]	Alluvium/weathered Mancos Shale form (concentration)	Tres Hermanos-C Sandstone form (concentration)
Nitrate	NO_3^- (329)	NO_3^- (56.76)	NO_3^- (55.18)
Selenium	SeO_3^- (0.10)	$HSeO_3^-$ (0.43)	$HSeO_3^-$ (0.118)
Molybdenum	MoO_4^- (115)	MoO_4^{2-} (33.87)	MoO_4^{2-} (0.147)
Uranium	$UO_2(CO_3)_3^{4-}$ (7.18)	$UO_2(CO_3)_3^{4-}$ (3.67)	$UO_2(CO_3)_3^{4-}$ (1.87)

[a]Concentration units in mg/l.

Table D.8.24 Saturation indices for Ambrosia Lake site, New Mexico

Solid Phase	Tailings pore fluid	Alluvium/weathered Mancos Shale	Tres Hermanos-C Sandstone	Westwater Canyon Member
Uraninite	-7.45	-3.10	-0.58	-5.02
Amorphous Uranium Dioxide	-13.26	-8.98	-6.46	-10.82
Calcite	1.40	0.85	0.49	0.58
Gypsum	-0.48	0.25	0.11	-0.3
Hematite	18.57	12.85	11.33	16.85
Pyrite	-80.41	-65.63	-51.26	-90.24
Siderite	1.20	-0.32	-0.11	-0.76
		Ferric Oxyhydroxides		
Lepidocrocite	6.27	3.54	2.78	5.37
Ferric hydroxide ($FeOH_3$)	4.96	2.24	1.48	4.06
Goethite	6.81	3.96	3.19	5.94
Ferrihydrite	2.75	0.02	-0.74	1.85

Table D.8.25 Comparison of observed and simulated aqueous species at the Ambrosia Lake site, New Mexico

Species	Tailings pore fluid	Mill make-up water	Mixing ratio (Mill make-up water: tailings water) 0.30	0.40	0.50	0.60	0.65	Alluvium/weathered Mancos Shale
			(Log molalities)					
Carbon	-1.12	-2.22	-2.18	-1.32	-1.39	1.48	-1.52	-1.68
Chloride	-2.47	-2.22	-2.38	-2.35	-2.33	-2.30	-2.29	-2.22
Iron	-4.91	-5.40	-5.01	-5.04	-5.10	-5.14	-5.16	-5.11
Sulfate	-1.13	-1.79	-1.24	-1.29	-1.34	-1.40	-1.44	-1.40
Nitrate	-2.27	-5.79	-2.42	-2.49	-2.57	-2.67	-2.72	-3.05
Uranium	-4.52	-5.03	-4.62	-4.66	-4.70	-4.75	-4.77	-4.80
Molybdenum	-2.91	-4.72	-3.06	-3.13	-3.21	-3.30	-3.36	-3.45

Table D.8.26 Comparison of Tres Hermanos-C Sandstone[a] and Westwater Canyon Member[b] groundwaters

	Unit of Measurement	Tres Hermanos-C Sandstone	Westwater Canyon Member
Antimony	mg/l	0.011	---
Arsenic	mg/l	0.007	0.095
Barium	mg/l	0.070	0.172
Beryllium	mg/l	0.003	---
Cadmium	mg/l	0.002	0.024
Chromium	mg/l	0.074	0.078
Cobalt	mg/l	0.042	0.059
Copper	mg/l	0.022	0.066
Cyanide	mg/l	0.070	---
Fluorine	mg/l	0.748	---
Lead	mg/l	0.005	0.48
Mercury	mg/l	0.0002	<0.002
Molybdenum	mg/l	0.147	2.008
Nickel	mg/l	0.063	0.140
Nitrate	mg/l	55.178	0.11
Selenium	mg/l	0.118	0.198
Silver	mg/l	0.018	0.053
Sulphide	mg/l	0.065	---
Thallium	mg/l	0.002	---
Tin	mg/l	0.011	---
Uranium	mg/l	1.875	2.24
Vanadium	mg/l	0.106	0.010
Zinc	mg/l	0.045	0.22
Gross Alpha	pCi/l	503	0
Radium 226 & 228	pCi/l	5.028	28

[a]Mean concentration of values from DOE groundwater quality data base on file at UMTRA Project Office, Albuquerque, New Mexico.
[b]Mean concentration of values from Table D.8.8.
Note: "---" means not analyzed.

Table D.8.27 Records of wells within five miles of the Ambrosia Lake site

Owner or well name[a]	Principal aquifer[b]	Location no.	Total depth (ft)	Year constructed	Use[c]
A. Berryhill	JM	14.9.18.243	800	1957	D
A. Berryhill	JM	14.9.32.314	550	--	-
Marvin Marquez	JM?	13.9.15.34	300	--	D
Marvin Marquez	--	13.9.15.34	--	--	D
Phil Harris	--	13.9.16.422	--	--	D
Phil Harris	S	14.9.17	>3000	--	S
Phil Harris	S	13.9.13	>3000	--	S
Jerry Elkins	JM?	14.10.14.214	--	--	D and S

[a]Does not include observation wells or known abandoned wells.
[b]JM = Westwater Canyon Member, Morrison Formation; S = San Andres Limestone.
[c]D is domestic; S is stock.
Ref. NMEID, 1987; Marquez, 1985; Baughman, 1985b; Brod and Stone, 1981.

D.9 METEOROLOGICAL DATA

D.9.1 PURPOSE

Meteorological data are provided to:

- o Estimate the length of the construction season.
- o Plan construction dust control.
- o Plan construction runoff control.
- *o Design long-term erosion control.*
- o Determine long-term moisture content of cover materials.
- o Determine any extraordinary protection required for personnel or equipment.

D.9.2 WEATHER PATTERNS

The climate of the Ambrosia Lake area is characterized by low precipitation, abundant sunshine, low relative humidity, and moderate temperatures with large diurnal and annual ranges. The regional climate is classified as semi-arid and continental (QMC, 1981).

D.9.3 WIND

The topography in the area suggests a wind regime dominated by two major influences: nighttime drainage of cold air from the high mesas, and channeling of synoptic winds through the northwest-southeast oriented valley (QMC, 1981).

The wind data from a meteorological station operated by the New Mexico Environmental Improvement Division (NMEID) 0.25 mile north of the tailings pile are presented in Table D.9.1 and Figure D.9.1. The predominant wind directions observed were westerly and north-northwesterly.

Wind data from the combined National Weather Service Stations at Acomita and Grants, New Mexico, are considered representative of regional wind conditions. Wind data from this station are presented in Table D.9.2. At the Acomita-Grants weather station, 17 miles southeast of the tailings site, the annual average wind speed is 9.3 miles per hour (all directions); the most frequent wind directions are from the west (19.6 percent) and northwest (13.1 percent). Calm conditions occur 6.6 percent of the time (FBDU, 1983).

D.9.4 TEMPERATURE

The Ambrosia Lake area exhibits a large diurnal range in temperature, which is conducive to nighttime inversion formations. Ten and one-half months of measurements at the NMEID monitoring site show a mean daily minimum of 40.9°F, and a mean daily maximum of 65.2°F. The mean daily average of 53.5°F agrees reasonably well with the long-term (1962-1974) average of 49.2°F measured at the Floyd Lee Ranch near San Mateo, New Mexico, 13 miles southeast of the tailings site (QMC, 1981).

Gulf Mineral Resources Company has established several meteorological monitoring stations in the Mt. Taylor area. Temperature data from station No. 1 at 7280 feet near San Mateo, New Mexico, are given in Table D.9.3 for a one-year period between February, 1976, and January, 1977 (QMC, 1981). Temperatures at this station are expected to be somewhat lower than those at the tailings site due to the difference in elevation between the two locations.

D.9.5 PRECIPITATION

Most of the precipitation in the project area occurs during the late summer thunderstorm season, although there is considerable monthly and annual variation in total rainfall. Table D.9.4 presents long-term precipitation measurements made at San Mateo (Floyd Lee Ranch) and three other regional stations. The long-term annual average for San Mateo was 8.83 inches with a maximum of 13.55 inches in 1956. August was the wettest month with an average of 2.13 inches, and a maximum of 4.38 inches in 1948. Most of the winter precipitation in this area falls as snow (QMC, 1981).

D.9.6 FROST

Freezing and thawing of the surface occurs frequently from December through March. The average annual frost-free period is 120 days (NOAA, 1979). The average maximum frost penetration in soils in the Ambrosia Lake area based on a 40-year period of record (1944-1984) is 24 inches (Losito, 1985).

D.9.7 EVAPORATION

The mean annual lake evaporation in the area is 54 inches. Seventy-two percent of the annual evaporation occurs from May through October (NOAA, 1979).

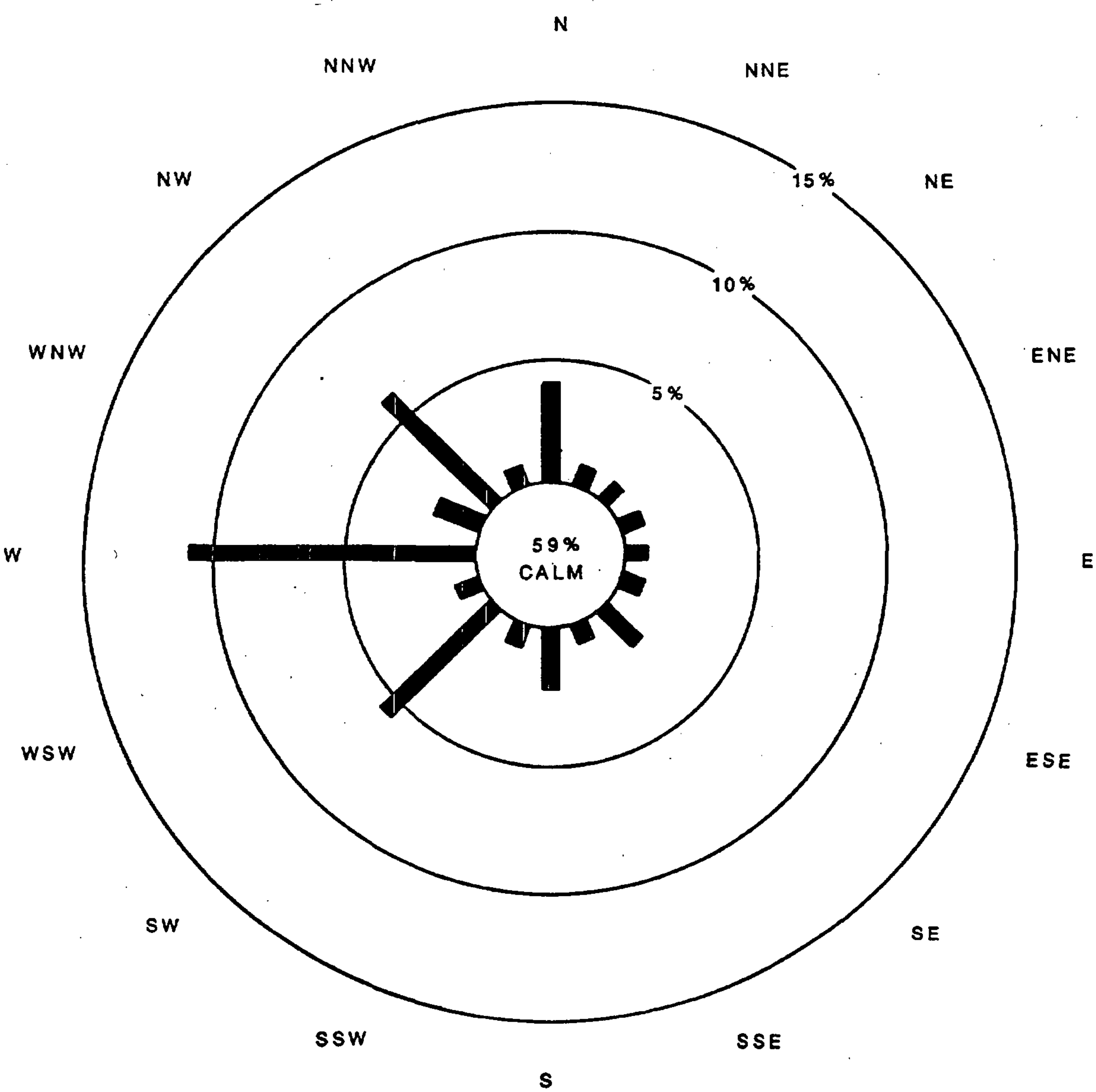


FIGURE D.9.1
AMBROSIA LAKE SURFACE WIND ROSE: CUMULATIVE DATA FOR 1974

Table D.9.1 Wind speed and direction and joint frequency distribution

	Wind speed class (mph)						
	1-3	4-7	8-12	13-18	19-24	>24	Total
N	187	180	40	7	0	0	414
NNE	302	152	20	2	0	0	476
NE	214	43	12	1	1	0	271
ENE	145	17	7	6	0	0	175
E	185	23	6	2	0	0	216
ESE	107	53	23	9	0	0	192
SE	131	73	22	3	1	0	230
SSE	119	56	21	8	2	0	206
S	136	140	85	31	2	0	394
SSW	87	135	121	35	5	0	383
SW	94	74	82	42	9	0	301
WSW	81	90	99	87	12	0	369
W	133	153	169	127	28	0	610
WNW	84	102	88	50	14	1	339
NW	170	120	86	57	11	1	445
NNW	254	202	112	26	5	1	600
TOTAL	2429	1613	993	493	90	3	

NOTE: Number of calms were 20.
Total number of occurrences were 5641.

Ref. QMC, 1981.

Table D.9.2 Wind data for the Acomita-Grants, New Mexico, National Weather Service Station

Monthly average wind speed and directional frequency distribution[a]

Month	Average wind speed (mi/hr)	Frequency of calms (percent)	Most frequent direction: Direction	Most frequent direction: Frequency (percent)
January	10.8	3.9	W	23.7
February	9.8	2.4	W	21.8
March	12.0	4.4	W	28.1
April	11.5	5.9	W	28.0
May	10.4	6.5	W	19.9
June	10.4	8.3	W	19.4
July	9.0	11.5	W	13.5
August	7.9	13.2	W	12.9
September	8.9	8.1	NW	13.6
October	9.4	6.6	W	15.0
November	11.0	3.5	NW	20.8
December	10.1	4.1	W	21.7
Annual	9.3	6.6	W	19.6

Directional distribution[b]

Direction	Frequency (percent)	Direction	Frequency (percent)
N	2.3	SSW	2.0
NNE	0.6	SW	7.9
NE	1.3	WSW	9.1
ENE	1.3	W	19.6
E	5.2	WNW	11.3
ESE	5.2	NW	13.1
SE	5.6	NNW	4.7
SSE	2.4	Calm	6.6
S	2.0		
		Total	100.2

[a]Period of record is for the two stations combined, as follows: Acomita, January, 1950, to April, 1953; Grants, May, 1953, to December, 1954.

[b]The data format of this source does not permit calculation of directional wind velocities.

Ref. FBDU, 1983.

Table D.9.3 Monthly and annual means and extremes of temperatures (°F) Mt. Taylor uranium mill project monitoring site number 1, elevation 7280 feet MSL

Month	Mean	Mean daily maximum	Mean daily minimum	Maximum	Minimum
1976					
February	37.1	46.2	28.7	58.0	14.0
March	34.6	45.6	22.5	63.0	10.5
April	48.0	57.3	36.9	65.5	19.0
May	55.2	64.7	45.1	76.0	30.0
June	64.5	75.1	52.8	84.0	42.0
July	67.3	78.3	57.1	86.0	52.0
August	66.2	76.5	56.7	83.0	44.5
September	59.8	70.4	49.8	82.0	39.5
October	48.3	57.6	38.9	72.0	29.5
November	38.8	49.8	28.3	62.0	5.0
December	31.9	43.8	22.4	58.0	10.0
1977					
January	28.5	38.3	20.3	48.0	3.0
Annual	48.4	58.7	40.3	86.0	5.0

Period of record: February 11, 1976, to January 31, 1977.

Ref. QMC, 1981.

Table D.9.4 Monthly and annual average precipitation (inches) for San Mateo, Grants, Marquez, and San Fidel, New Mexico

Month	San Mateo[a]	Grants[b]	Marquez[c]	San Fidel[d]
January	0.42	0.36	0.45	0.37
February	0.38	0.39	0.49	0.46
March	0.40	0.45	0.57	0.44
April	0.43	0.36	0.67	0.65
May	0.37	0.43	0.70	0.79
June	0.47	0.69	0.73	0.79
July	1.72	1.81	1.79	1.65
August	2.13	2.18	2.71	2.02
September	1.14	1.17	1.20	1.43
October	0.75	1.07	1.31	0.61
November	0.33	0.33	0.51	0.41
December	0.44	0.62	0.55	0.47
Annual	8.83[e]	10.04	11.68	10.9

[a]Elevation 7250 feet MSL; period of record 1939-1974.
[b]Elevation 6480 feet MSL; period of record 1946-1960.
[c]Elevation 7620 feet MSL; period of record 1941-1970.
[d]Elevation 6160 feet MSL; period of record 1920-1954.
[e]Twenty-four years data available for annual mean.

Ref. QMC, 1981.

D.10 SURFACE WATER HYDROLOGY

D.10.1 PURPOSE

Surface water hydrology data are required to:

- o Characterize existing surface water conditions.
- o Evaluate flood protection requirements.
- o Evaluate the effect of surface runoff on surrounding areas.
- o Assess watercourse cleanup or channelization requirements.
- o Design facilities to protect water quality during construction.

D.10.2 GENERAL

The major watercourse in the Ambrosia Lake area is the Arroyo del Puerto (Figure D.10.1), a southeast-meandering tributary of San Mateo Creek. One mile southwest of the designated site and paralleling New Mexico Highway 509, the arroyo is at an elevation of 60 to 80 feet below the tailings pile. Though the arroyo is the principal drainage from the Ambrosia Lake valley, flow in the low gradient stream is minimal. Flow in the Arroyo del Puerto is augmented by seepage from the Quivira Mining Company (QMC) ponds southwest of the designated site, and discharge from the QMC and Homestake ion-exchange plants.

Arroyo del Puerto is incised primarily into Quaternary alluvium which, in the valley bottom, exceeds 100 feet in thickness. The Crevass Canyon Formation and Mancos Shale are the parent sources of the alluvium (Purtymun et al., 1977). In several areas, especially near the confluence of the arroyo with San Mateo Creek, the Dakota Sandstone underlies the channel. Purtymun et al. (1977) suggest that losses of water into underlying sandstones is greater than into the Mancos Shale and associated detritus. The present semi-arid geomorphic environment precludes the possibility of lateral shifting of the Arroyo del Puerto in a manner that could endanger the tailings pile. Potential changes in the area drainage network are discussed in detail in Section D.4.5.1 of this Appendix.

Many smaller first- and second-order ephemeral streams are tributary to the Arroyo del Puerto. The majority flow from San Mateo Mesa toward the south-southwest. Stream density southwest of the Arroyo del Puerto is much less due to the more resistant nature of the sandstone which caps Mesa Montanosa. Two of the smaller tributaries which affect the tailings pile are indicated in Figure D.10.1. Spreading of contaminants from the pile as a result of erosional processes and transport into the channels will continue as long as the tailings pile remains unstabilized.

D.10.3 DRAINAGE AND HISTORICAL FLOWS

The Arroyo del Puerto was gauged by the USGS for three years from October, 1979, to September, 1982. Monitoring of the gauge was discontinued due to little or no flow in the channel. The maximum recorded discharge during the gauge period was about 6.8 cfs (Borland, 1985). Flow in the arroyo is generally lost to evapotranspiration and channel infiltration five miles south of the designated site (FBDU, 1983). Loss of flow due to evapotranspiration is greater during summer months (FBDU, 1983). No regular flow occurs in the arroyo upstream of the discharge point from the Homestake Mining Company ion-exchange plant.

The watershed above the tailings pile and mill site covers an area of 3.14 square miles. Purtymun et al. (1977) reports that two ephemeral channels carry runoff toward the pile from an area northeast of the site on Roman Hill. The northern channel discharges runoff near the base of the northern edge of the tailings pile and is 12,470 feet long with a gradient of 0.09. The gradient decreases rapidly to 0.03 as the channel emerges into the valley 3600 feet north of the tailings pile. Adjacent to the pile, the channel branches out and disappears into a catchment area containing some 100 exploration pits and broad depressions (Figure D.10.1). The eastern channel discharges runoff into two ponds east of the mill and is 7550 feet long with a gradient of 0.03 (Purtymun et al., 1977).

A minor drainage network has developed along the western side of the pile where outcropping silty sandstone was removed to construct the lower part of the tailings impoundment. In 1977, no erosion in the bedrock near the lower part of the dike by this channel was apparent. There is significant channel incision in the soil close to the northwest corner of the pile (Purtymun et al., 1977). Precipitation runoff and suspended contaminants from at least the western slope of the tailings pile are transported away from the designated site in this channel. Haywood et al. (1980) found that the transport of tailings by water erosion had occurred in all directions from the pile.

The top of the tailings pile is composed primarily of silty tailings. The material is eroded by runoff which transports the tailings into the central tailings pond as well as down the outer edges of the dike (Purtymun et al., 1977). Evaluation of 1:24,000 scale orthophotoquad photographs of the pile confirms that the western (~591 feet north of the southwest pile corner) and southern (~295 feet east of the southwest corner) impoundments have been breached by erosion. This was also reported by Purtymun et al. (1977). No specific causes or events were cited by the researcher.

As shown on Figure D.10.1, there are six ponds in the drainage area of the mill site and tailings pile. Two ponds northeast and immediately adjacent to the mill, and a third in the embayment of the north edge of the tailings pile, were used as runoff containment ponds to buffer storm flow. A large double pond adjacent to the northeast pile corner served as the mine-water discharge and evaporation pond for the Ann Lee mine. Sewage effluent was contained in the depression close to the east edge of the pile. The northeast pond most distant from the designated site served and continues to be intermittently used as a livestock watering tank.

Following a 0.9-inch rainfall on August 19, 1976, the pond in the north pile embayment filled to within inches of the top of the impoundment. Breaching the dike on August 21, water flowed into the basin within the pile. The breach in the dike was 16 feet long and two feet deep and was downcut to an elevation of 7000 feet. The overflow eroded a deep channel into the surface of the pile as water filled the basin, creating a pond of about 646,000 square feet. The volume of tailings removed from the channel is estimated to be 20,000 cubic feet. The transported tailings formed a delta extending southward into the pond. The volume of inflow was calculated as 335 cubic feet from high water marks on the north side of the dike (Purtymun et al., 1977).

D.10.4 FLOOD ANALYSIS

An analysis of a PMF resulting from a six-hour general storm in the vicinity of the Arroyo del Puerto was conducted by Quivira Mining Company at the request of the New Mexico State Engineer's Office to evaluate the effects of a flood on the Quivira Mining Company (Kerr-McGee) tailings pile. The U.S. Army Corps of Engineers HEC programs were used to model flood flows. Flood levels in the Arroyo del Puerto during a PMF would be over 40 feet below and one mile away from the Ambrosia Lake site; therefore, such a flood would not be a hazard to the stabilized tailings pile.

Flood analysis for the Ambrosia Lake site was performed to determine the effects of and design criteria for two distinct precipitation events. Probable Maximum Precipitation (PMP) on the stabilized embankment was analyzed to determine on-pile erosion protection requirements. A PMP event in the watershed above the embankment would generate a Probable Maximum Flood (PMF). This calculation was used to determine erosion protection and drainage required to withstand the flood flows.

The PMP event

The PMP is theoretically the greatest intensity of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location. Hydrometeorological Report #55 (DOC, 1977a) was used to generate this value. The one-hour, local storm PMP of 10.67 inches was obtained from isopluvial charts contained in HMR #55. This includes allowances for the site elevation, the maximum 12-hour dewpoint, and areal reduction factors.

This PMP intensity was used as input in the erosion protection analyses of the conceptual design. Additional PMP calculations to support the final design in Appendix B, Engineering Design, have been prepared by the RAC.

The PMF event

The drainage basin above the Ambrosia Lake site is divided into two distinct drainages which impact separate portions of the site.

The drainage area which collects runoff that could impact the north side of the embankment covers 1555 acres. The north drainage is subdivided into four units based on slope changes and internal drainage networks. The upper two subunits are steep and rocky, begin at the crest of San Mateo Mesa, and end where their drainages meet. The middle subunit has an established arroyo which cuts through the alluvial slope. The lowest subunit is a gently sloping region with no well-established drainage network.

The eastern drainage consists of three subunits totaling 457 acres. The upper subunit consists of a relatively steep canyon on the east side of Roman Hill. The mid subunit includes the catchment leading to a stock watering pond, while the lower unit is the approach slope to the mill site. The lower part of the east drainage includes an incised gully which formed below the stock tank, and leads to an interceptor ditch which diverts water southwest, to Voght Tank. The interceptor ditch and stock tanks were assumed to have no impact on the 1000-year design.

Additional design information on drainage basins and subunits was developed for input into the HEC-1 computer model (COE, 1981). This additional information includes area and slope calculations, time of concentration by the Kirpich method (AISI, 1971), and lag times of the subunits (DOI, 1977). A six-hour local storm PMF hydrograph was developed by methods described in HMR-49 (DOC, 1977b).

Computer modeling was performed for the watersheds for conditions of combined and routed sub-basins with ranges of infiltration rates and SCS soil curve numbers. Maximum modeled flow rates were obtained using a routing/combining format with a 0.2 infiltration rate.

Maximum HEC-1 model flow rates were 22,624 cubic feet per second (cfs) in the north drainage, and 7292 cfs in the east drainage. Additional PMF calculations to support the final design in Appendix B, Engineering Design, have been prepared by the RAC.

D.10.5 SURFACE WATER QUALITY

Water quality was analyzed from nine locations near the Ambrosia Lake tailings site, and along San Mateo Creek and Arroyo del Puerto (FBDU, 1983; NMEID, 1980; Gallaher and Goad, 1981) (Figure D.10.1). A total of 30 constituents was analyzed from samples near the tailings pile, Arroyo del Puerto, and San Mateo Creek (Table D.10.1) and a second set of eight constituents was sampled from the arroyo and creek (Table D.10.2). Analysis of these data on a trilinear diagram (Figure D.10.2) reflects the differences in water chemistry between San Mateo Creek and Arroyo del Puerto. Arroyo del Puerto and downstream sections of the San Mateo Creek are affected by seepage from the Quivira Mine tailings pond and mine water discharges from the Ambrosia Lake area as evidenced by high calcium-sulfate content in surface waters (Table D.10.1). Because flow in Arroyo del Puerto is sustained almost entirely by groundwater discharge from mines, definition of surface water quality is not applicable to the Arroyo del Puerto.

Surface water which could be potentially affected by contamination from the Ambrosia Lake tailings site, only occurs occasionally as ponded runoff during excessive precipitation events. There was no ponded water near the site to be sampled during the October, 1985, investigation. A sample (location 665 on Figure D.10.1) from the surface pond on the tailings was collected in May, 1986. Chemical analyses of this sample are presented in Table D.10.1.

Samples 604, 605, and 606 were collected from intermittent surface water ponds at the Ambrosia Lake tailings site, which are presently dry. At the time of sampling (1981), localized ponded water at the site contained levels of arsenic, iron, selenium, and, in one case, cadmium, which exceeded state or Federal water-quality standards (Table D.10.3).

APPENDIX E

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

E.1 WATER RESOURCES PROTECTION STRATEGY

Groundwater in the uppermost aquifer at the Ambrosia Lake disposal site qualifies for supplemental standards (40 CFR Part 192.11 (e)). The supplemental standard application is based on the insufficient yield of the alluvium/weathered Mancos Shale and Tres Hermanos-C Sandstone that comprise the uppermost aquifer beneath the Ambrosia Lake site. The uppermost aquifer is incapable of producing 150 gallons per day or more for a sustained period of time which classifies it as limited use (class III) groundwater (Section D.8.4 of Appendix D). In addition to insufficient yield, the water contained in the alluvium/weathered Mancos Shale and Tres Hermanos-C Sandstone is of poor quality and cannot be used for drinking or other beneficial purposes.

The hazardous constituents within the tailings pore fluids at Ambrosia Lake are mostly metal and metalloid elements associated with the uranium milling process. Concentrations of arsenic, barium, cadmium, lead, molybdenum, nitrate, selenium, silver, uranium, and activities of gross alpha, radium -226 and -228 exceed the Maximum Concentration Limits (MCLs) established by the U.S. Environmental Protection Agency (EPA) in at least one tailings pore water sample collected from lysimeters or well points. Antimony, cobalt, copper, cyanide, fluoride, nickel, tin, vanadium, and zinc are inorganic hazardous constituents without MCLs, but were present in tailings pore fluid at concentrations higher than the laboratory method detection limit. No organic hazardous constituents were above laboratory method detection limits.

For this supplemental standards application, no concentration limits or point of compliance have been specified. This is justified considering that uranium processing activities established the condition of saturation in the alluvium/weathered Mancos Shale and the Tres Hermanos-C Sandstone. As part of the supplemental standards application, a risk assessment was performed to evaluate whether supplemental standards would protect human health and the environment from the consumption of groundwater in the uppermost aquifer. The risk assessment considered the hypothetical use of the uppermost aquifer as a source of drinking water. The results of the risk assessment indicate that there would be noncarcinogenic health effects associated with the long-term consumption of the groundwater. In addition, short and long-term carcinogenic health effects may occur. The concentration of uranium in the groundwater was the major contributor to carcinogenic risk. However, the likelihood of consumption of groundwater from the alluvium/weathered Mancos Shale and Tres Hermanos-C Sandstone is negligible because groundwater cannot be developed due to insufficient yield. Furthermore, the area of saturation is covered mostly by the tailings and the confines of the site boundaries, providing positive institutional control over the use of groundwater. A review of land and water use patterns in the site vicinity supports the application of supplemental standards. An engineering evaluation of the proposed remedial action design determined that the disposal cell protects human health and the environment by incorporating design features that are as close to meeting the otherwise applicable standard as is reasonably achievable.

Consumption of groundwater from the Westwater Canyon Member may also result in carcinogenic and noncarcinogenic health effects. Contaminated groundwater may have migrated down mine shafts and vent holes into the

Westwater Canyon Member. The Westwater Canyon Member is a source of drinking water in the area, but due to mining in the region, water quality has already deteriorated to the extent that there is some risk to human consumption. Groundwater in the Westwater Canyon Member exceeds the MCLs for cadmium, chromium, lead, molybdenum, selenium, silver, and uranium and activities of radium -226 and -228. However, mixing of contaminated groundwater from the Ambrosia Lake site with the Westwater Canyon Member groundwater has negligible effect on water quality in the Westwater and results in no additional risk to humans.

The proposed disposal cell cover at the Ambrosia Lake site is a low hydraulic conductivity clay radon barrier (saturated hydraulic conductivity of 1×10^{-7} centimeters per second (cm/s)), overlain by a high hydraulic conductivity (0.1 cm/s) filter layer and an erosion protection layer. The radon barrier will limit steady state vertical seepage (flux) through the tailings to 1×10^{-7} cm/s. This flux is lower than the drainage capacity of the alluvium/weathered Mancos Shale, preventing tailings seepage from perching on the contact between the base of the tailings and the alluvium/weathered Mancos Shale. Because this flux is approximately equal to natural recharge at the Ambrosia Lake site, tailings seepage will not create a condition of saturation in the alluvium/weathered Mancos Shale at the contact with the Mancos Shale.

Following closure of the disposal cell, active maintenance of the cell will be minimized because it will be built with durable, natural materials meeting the longevity requirements of 40 CFR Part 192.02. Furthermore, the disposal cell is designed to accommodate natural forces such as erosion and frost heave.

A surveillance and maintenance (S&M) plan will be developed to address the various monitoring needs of the disposal cell, including biointrusion and soil erosion. The data collected will be used to evaluate the performance of the disposal cell.

The need for and extent of groundwater restoration at the Ambrosia Lake site is based on the extent of existing contamination, the potential for current or future use of the alluvium/weathered Mancos Shale and Tres Hermanos -C Sandstone for drinking water supplies, and the technical practicability of restoring the aquifer. Because groundwater in the alluvium/weathered Mancos shale and Tres Hermanos-C Sandstone (the uppermost aquifer) is Class III, groundwater clean-up is unwarranted. There is insufficient yield in the uppermost aquifer for it to be considered a water resource and, therefore, it cannot be put to beneficial use. The low yield makes groundwater clean-up technically impracticable.

By not performing groundwater clean-up, the DOE is still protecting human health and the environment because there is no present or predicted future use of groundwater in the uppermost aquifer.

E.2 CONCEPTUAL DISPOSAL CELL DESIGN FEATURES TO PROTECT WATER RESOURCES

The disposal cell cover system being considered for the Ambrosia Lake site is a low hydraulic conductivity clay radon barrier overlying the tailings. The radon barrier will serve as the primary infiltration barrier and will be overlain by a high-hydraulic conductivity filter layer, which will divert water rapidly off the pile. This will be overlain by an erosion protection layer consisting of rock riprap.

The disposal cell will be constructed on the unconsolidated alluvium/weathered Mancos Shale. A cross section of the disposal cell is shown on Figure E.2.1. Additional information on the geology at the Ambrosia Lake site is presented in Section D.4 of Appendix D.

E.2.1 DESIGN CONSIDERATIONS

Design considerations for the disposal cell include identifying natural infiltration rates and rates of drainage into the underlying materials to ascertain whether seepage from the disposal cell will continue to create a condition of saturation in the alluvium/weathered Mancos Shale at the contact of the unweathered Mancos Shale. Long-term seepage from the disposal cell is a function of the unsaturated hydraulic conductivity of the radon barrier and the transient rate of drainage of moisture already in the tailings. Field studies at other disposal sites with similar cover designs and climate and unsaturated flow modeling of the radon barrier suggest that the radon barrier will remain unsaturated during the design life of the disposal cell (DOE, 1989).

E.2.1.1 Natural infiltration

Naturally occurring infiltration into the alluvium/weathered Mancos Shale was considered in the design of the disposal cell. A condition of saturation in the alluvium/weathered Mancos Shale could occur at the contact with the unweathered Mancos Shale below the disposal cell if infiltration through the tailings is significantly greater than natural ambient infiltration. Because the alluvium/weathered Mancos Shale is in some areas only 10 feet thick, it is a consideration that saturation does not extend up into the tailings. Thus, infiltration through the radon barrier must be restricted to a flux that is less than the natural ambient infiltration.

Natural infiltration may be estimated from the annual precipitation. In semiarid regions, infiltration is often one or two percent of the annual precipitation (Rush et al., 1982). The average annual precipitation for Ambrosia Lake is 8.8 inches (QMC, 1981). If the annual precipitation at the site is conservatively assumed to be 12 inches and infiltration to groundwater is less than two percent of precipitation, infiltration would be less than 0.24 inch a year, equivalent to an annual flux of less than 2×10^{-8} cm/s.

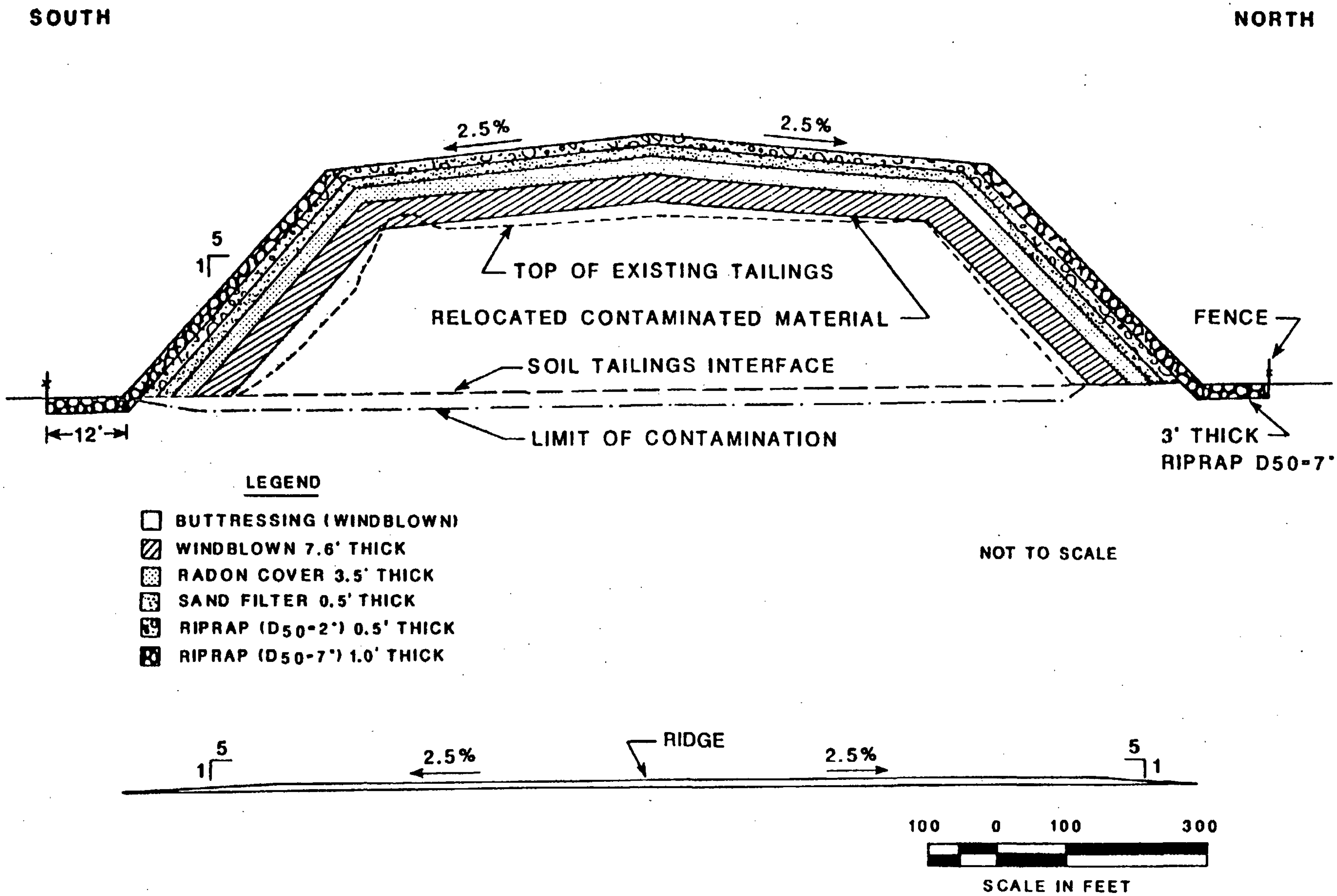


FIGURE E.2.1
TYPICAL CROSS SECTION OF DISPOSAL CELL
AMBROSIA LAKE SITE, NEW MEXICO

Most of the alluvium/weathered Mancos Shale at the site would not be saturated, if uranium processing activities had not discharged tailings or seepage from the mill make-up pond. By designing the radon barrier with less infiltration than ambient natural infiltration, no saturation will develop at the contact of the alluvium and weathered Mancos Shale.

E.2.1.2 Transient drainage of tailings fluids

Seepage of water from the tailings pile continues to be a source of saturation of the alluvium/weathered Mancos Shale and the Tres Hermanos C sandstones. However, groundwater levels are not currently high enough to mound into the tailings and surface seeps have not been observed near the tailings pile. Because the seepage rate from the tailings will be less after remedial action than what is presently observed, mounding of seepage at the contact between the alluvium/weathered Mancos Shale and the competent Mancos Shale or the creation of surface seeps should not be a problem. Water use during construction will be limited so that the tailings will not become saturated and potentially cause an increase in the rate of seepage. The current trend of decreasing seepage is expected to continue during construction and in the post construction period.

E.2.1.3 Subsurface drainage

Tailings seepage will generally perch on a low-hydraulic conductivity geologic unit wherever the vertical seepage flux is greater than the drainage capacity of the geologic unit. Under steady state conditions, this drainage capacity is equal to the saturated hydraulic conductivity of the unit. The saturated hydraulic conductivity of the alluvium/weathered Mancos Shale is 4.1×10^{-5} cm/s producing a drainage capacity greater than the infiltration rate (1×10^{-7} cm/s) of the radon barrier. For this reason there should be no perching of seepage at the base of the disposal cell.

Natural infiltration at Ambrosia Lake also does not exceed this vertical drainage capacity, because there is presently no significant quantity of perched surface water at the site other than that related to uranium processing. This is consistent with the estimate of a natural infiltration rate of less than 2×10^{-8} cm/s.

E.2.2 COVER DESIGN

The disposal cell cover at Ambrosia Lake will 1) restrict radon emanation into the atmosphere; 2) limit infiltration into the tailings; 3) limit or prevent erosion from surface flow; and 4) promote runoff across the pile, preventing surface ponding. The cover will also restrict seepage, thereby maintaining unsaturated conditions in the underlying materials. The seepage rate will be less than 1 x 10^{-7} cm/s, and will not result in contaminated seepage perching on the low-hydraulic conductivity alluvium/weathered Mancos Shale or create a condition of saturation at the contact of the unweathered Mancos Shale.

E.2.2.1 Cover components

This section describes the components of the cover design which limit infiltration into the tailings. The performance of the cover in terms of seepage flux and meeting the proposed EPA groundwater standards is also discussed.

Figure E.2.1 is a generalized cross section of the proposed disposal cell embankment and foundation. Table E.2.1 lists the functions of each component of the pile. The cover components described below are listed in ascending order.

Radon/infiltration barrier

The 3.5-foot-thick radon/infiltration barrier will reduce radon emissions into the atmosphere and will limit infiltration of precipitation into the tailings. The radon/infiltration barrier is designed with a saturated hydraulic conductivity of 1 x 10^{-7} cm/s. However, field studies on a similarly constructed disposal cell at Shiprock, New Mexico, indicate that long-term moisture contents are unsaturated, yielding a steady state unsaturated hydraulic conductivity of 1 x 10^{-9} cm/s (DOE, 1989). Seepage will occur primarily as unsaturated flow, and will not perch on the lower permeability alluvium/weathered Mancos Shale. Because this seepage flux is approximately equal to the natural infiltration rate at the Ambrosia Lake site, tailings seepage will not cause a condition of saturation in the alluvium/weathered Mancos Shale at the contact with the unweathered Mancos Shale.

Specifications:

The radon/infiltration barrier at the Ambrosia Lake site will be constructed of weathered Mancos Shale. The weathered Mancos Shale will be compacted to more than 100 percent standard proctor density. A sheep's foot-type compactor will be used in order to insure that adequate mixing and kneading of the shale takes place.

Performance:

By using a high degree of compaction, the saturated hydraulic conductivity of the radon barrier will be 1 x 10^{-7} cm/s. Because the climate at Ambrosia Lake is semiarid, the cover is expected to perform in an unsaturated condition. The long term flux through the unsaturated cover is expected to be much less than the saturated hydraulic conductivity.

Table E.2.1 Cover components and functions of disposal cell cover, Ambrosia Lake site, New Mexico

Cover component	Purpose and function
Erosion protection rock	o Provide protection against erosion of the radon/infiltration barrier o Reduce evaporation rate within the underlying layers and thereby preclude drying of the radon barrier o Protect underlying layers from the effects of frost heave and frost penetration
Filter layer	o Drain water laterally off the disposal cell to limit infiltration o Protect underlying radon/infiltration barrier from rock penetration o Protect the underlying radon/infiltration barrier from the effects of frost heave and frost penetration
Radon/infiltration barrier (weathered Mancos shale)	o Inhibit radon emanation o Limit infiltration

Longevity:

The radon/infiltration barrier will be protected by a sand/filter layer overlain by an erosion protection layer. These layers will protect the radon/infiltration barrier from eroding. The thicknesses of both the erosion protection layer and the radon/infiltration barrier is sufficiently thick that effects of freezing on the hydraulic conductivity in the lower portions of the radon/infiltration barrier are prevented. Because of these design features, the EPA design period will be met.

Filter layer

The sand filter layer above the radon barrier is designed to prevent erosion of the underlying radon barrier by interstitial flow and drain water rapidly off the pile. The filter layer will be six inches thick and constructed of a clean, high permeability (0.1 cm/s) sand.

Specifications:

The filter layer will be a clean sand and gravel with a hydraulic conductivity of 0.1 cm/s or greater. The gradation has been chosen to preclude damage of the radon/infiltration barrier. The gradation has also been selected to promote the shedding of the surface water as fast as possible.

Performance:

The filter layer will shed water off the pile, downslope and above the radon/infiltration barrier, thereby reducing the amount of water available for infiltration.

Longevity:

The EPA design period will be met.

Erosion protection layer

An erosion protection layer will be constructed over the filter layer. The erosion protection layer will protect the radon barrier and tailings embankment from runoff resulting from a Probable Maximum Precipitation event on the embankment and from runoff resulting from a Probable Maximum Flood (PMF) on the small watershed upslope of the embankment. The erosion protection layer is also designed to protect the embankment from the encroachment of gullies.

Specifications

The rock to be used for the Ambrosia Lake cover is a dense basalt which has been evaluated using standard Uranium Mill Tailings Action (UMTRA) Project procedures and U.S.

Nuclear Regulatory Commission (NRC) requirements. The rock is of sufficient quality to resist weathering processes and physical forces caused by wind and water.

Performance:

The rock will prevent erosion by flow in gullies. The rock is also sufficiently large to serve as a barrier against burrowing animals and encroaching vegetation.

Longevity:

The durable rock cover will meet the EPA design criteria.

ATTACHMENT 1

LAND AND WATER USE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

The following sections discuss the historical, current, and projected land use and water use in the vicinity of the DOE's Ambrosia Lake, New Mexico, UMTRA Project site. This discussion provides the information to support the supplemental standards application for the Ambrosia Lake site. Additional information and figures can be found in Appendix D.

2.0 DEFINITION OF STUDY AREA

The Ambrosia Lake tailings site is located approximately 20 miles north of the town of Grants in McKinley County, western New Mexico. The site is situated in the Ambrosia Lake valley in the Grants Uranium District (see Figure D.2.1 of Appendix D). In the 1970's, the Grants Uranium District was one of the most active in the United States, having between 38 and 45 mines in operation within a 50-mile radius of Grants. The 196 acre designated site currently consists of an approximately 111 acre tailings pile and piles of rubble from demolition of the abandoned mill buildings (see Figure D.2.2 of Appendix D).

The EPA has developed a draft groundwater classification process, which the DOE has adopted for defining Class III (limited use) groundwaters at UMTRA Project sites (DOE, 1989a; EPA, 1986). This classification system is not designed for use on a region-wide or aquifer-wide basis, and therefore relies on site-specific information. Consistent with the DOE policy for utilizing site-specific information, this land use and water use study encompasses, at a minimum, the area within a three-mile radius (28.3 square miles) of the Ambrosia Lake site (Figure 2.1). The three-mile radius area of study is termed the classification review area (CRA) for the purposes of groundwater classifications (DOE, 1989a). Since information for the Ambrosia Lake area is sparse, some data for areas outside the CRA are used in this discussion.

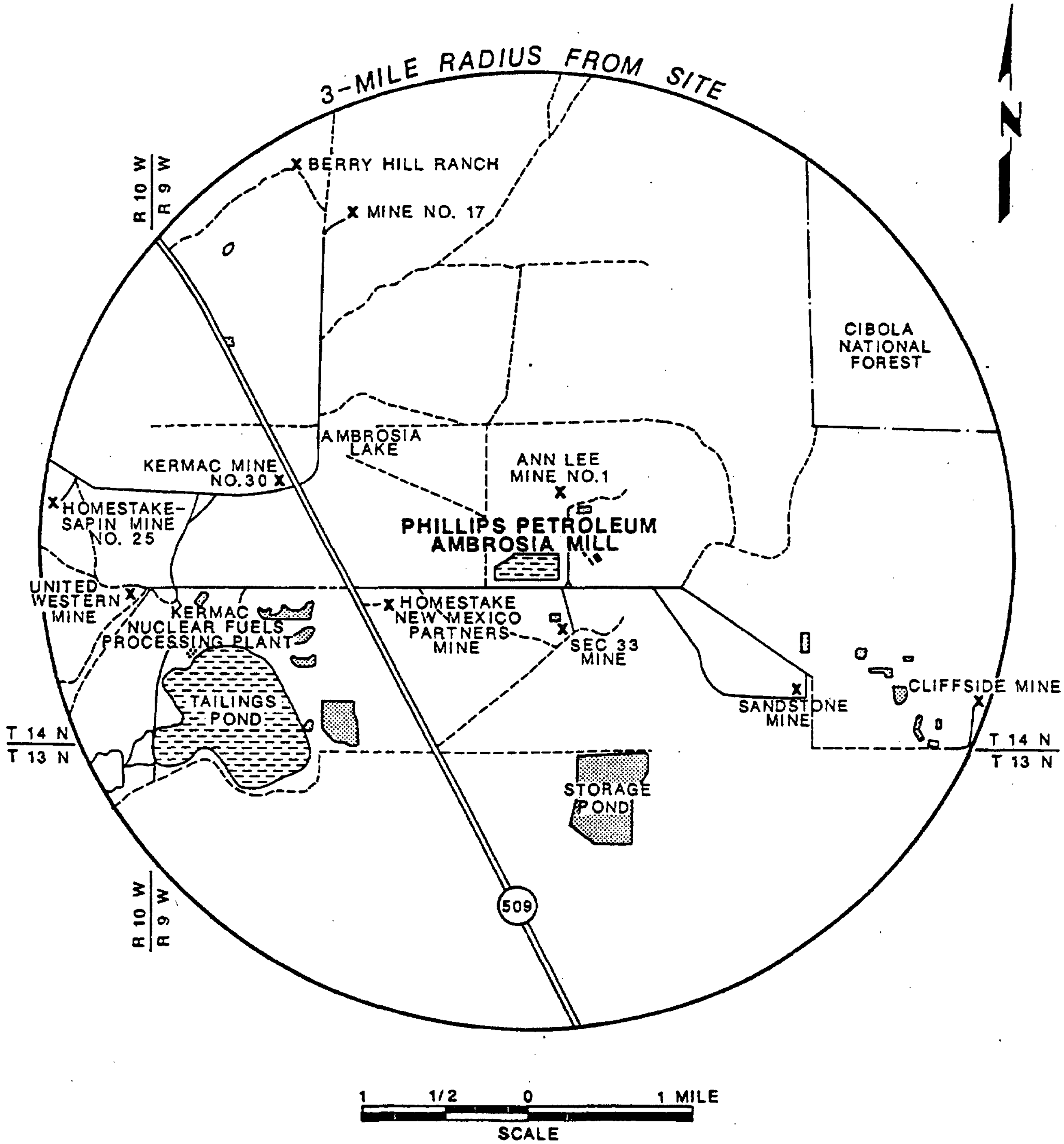


FIGURE 2.1
AMBROSIA LAKE CLASSIFICATION REVIEW AREA

3.0 BACKGROUND

The Ambrosia Lake tailings site is in Ambrosia valley in the Grants Uranium District in McKinley County. The closest town is San Mateo (unincorporated), approximately 15 air miles southeast of the site. The community of Ambrosia Lake is located approximately two miles northwest of the site. The nearest population center is Grants, a community of approximately 8900 people, which is in Cibola County. The land within the CRA is sparsely populated and is primarily used for mining and grazing (FBDU, 1983). The nearest residence is more than two miles northwest of the tailings site (Figure 2.1). Approximately 60 people live within a six-mile radius (DOE, 1987).

The topography of the area surrounding the site consists of broad, elongated valleys separated by basalt-capped mesas. The site lies within the drainage basin of Arroyo del Puerto, a tributary of San Mateo Creek. Arroyo del Puerto is an intermittent stream which lies approximately one mile southwest of the tailings site. Small ephemeral streams are also present north and east of the site and drain to the southwest.

The Ambrosia Lake area is semiarid with annual precipitation less than 11 inches. Plant species common to the area include Russian thistle, squirreltail grass, and snakeweed. Elevation in the general vicinity of the site is approximately 7000 feet above mean sea level. Soils in the area are of the Las Lucas-Little-Persayo association, which underlie and surround the tailings pile (see Figure D.4.6 and Section D.4.2.3 in Appendix D). Wildlife habitat near the site is marginal due to overgrazing and is dominated by grasses, herbs, and widely scattered shrubs (DOE, 1987).

4.0 POPULATION AND GROWTH

The Ambrosia Lake site is located in southeastern McKinley County, which is rural and sparsely populated. Although the site is located in McKinley County, the socioeconomic focus is primarily on Cibola County to the south and the Grants-Milan population center (see Figure D.2.1 in Appendix D).

The decline of the uranium industry in the early 1980s had a significant impact on the cities of Grants and Milan. Many workers associated with the uranium industry have left the area, as evidenced by the decline in the population of both Grants and Milan since 1980. The population of Grants was 11,439 in 1980 and had declined 22 percent to 8,965 by 1984. Similarly, the population of Milan declined 24 percent from 3,747 in 1980 to 2,831 by 1984. As a result of the population decline, Grants and Milan have a surplus of housing, and community services such as water, sewage treatment, and schools are operating significantly below capacity. The potential for growth is tied to any resurgence of the uranium industry, since there are no other major industries in the area other than ranching. Within the CRA, the population level is expected to stay at the current level, since ranching is the dominant land use in the area and will not generate significant populations changes.

5.0 CURRENT AND FUTURE LAND USE

5.1 CURRENT LAND USE

Historic land use in McKinley County was consistent with the primary land use of today, which is low-density grazing. Ninety percent of the land in the county is utilized for this purpose. Some land is also utilized jointly for grazing and mining. Commercial timber operations utilize approximately seven percent of the land. Less than one percent of the land in the county is used for raising crops, which include hay, grain and vegetables. Residential, commercial, or industrial land use occurs on relatively small segments of land within McKinley County. Land use within the CRA and within a five-mile radius of the site is shown in Figure 5.1.

Uranium was discovered in the Grants Mineral Belt in 1950 (NMEMD, 1979). Mining and milling of uranium deposits became the principal industry of the Ambrosia Lake valley until about 1980, when the demand for uranium declined (DOE, 1987). During the height of the industry, the Grants-Milan area realized increased populations and requirements for community services. Since 1981, uranium mining within McKinley County has declined dramatically, with over 90 percent of the uranium mines having ceased production (Durren, 1985).

5.2 FEDERAL LAND

The Federal government controls approximately 12 percent of the land in McKinley County, which is divided approximately equally between the U.S. Bureau of Land Management (BLM) and the U.S. Forest Service (FBDU, 1983). Some BLM and Forest Service land is located within the CRA (Figure 5.1).

5.3 TRIBAL LAND

About 61 percent of the land in McKinley County New Mexico is owned or managed by Indian tribes or the Bureau of Indian Affairs (BIA) (FBDU, 1983). Several parcels of tribal land or BIA land are located near the Ambrosia Lake tailings site. These lands are west and southwest of the site (Figure 5.1).

5.4 STATE LAND

The State of New Mexico controls less than five percent of the land in McKinley County (FBDU, 1983). Within the CRA, the State of New Mexico controls several parcels of land surrounding the site (Figure 5.1).

5.5 PRIVATE LAND

Less than 20 percent of the land in McKinley County is under private ownership. Parcels of privately owned land are scattered in all

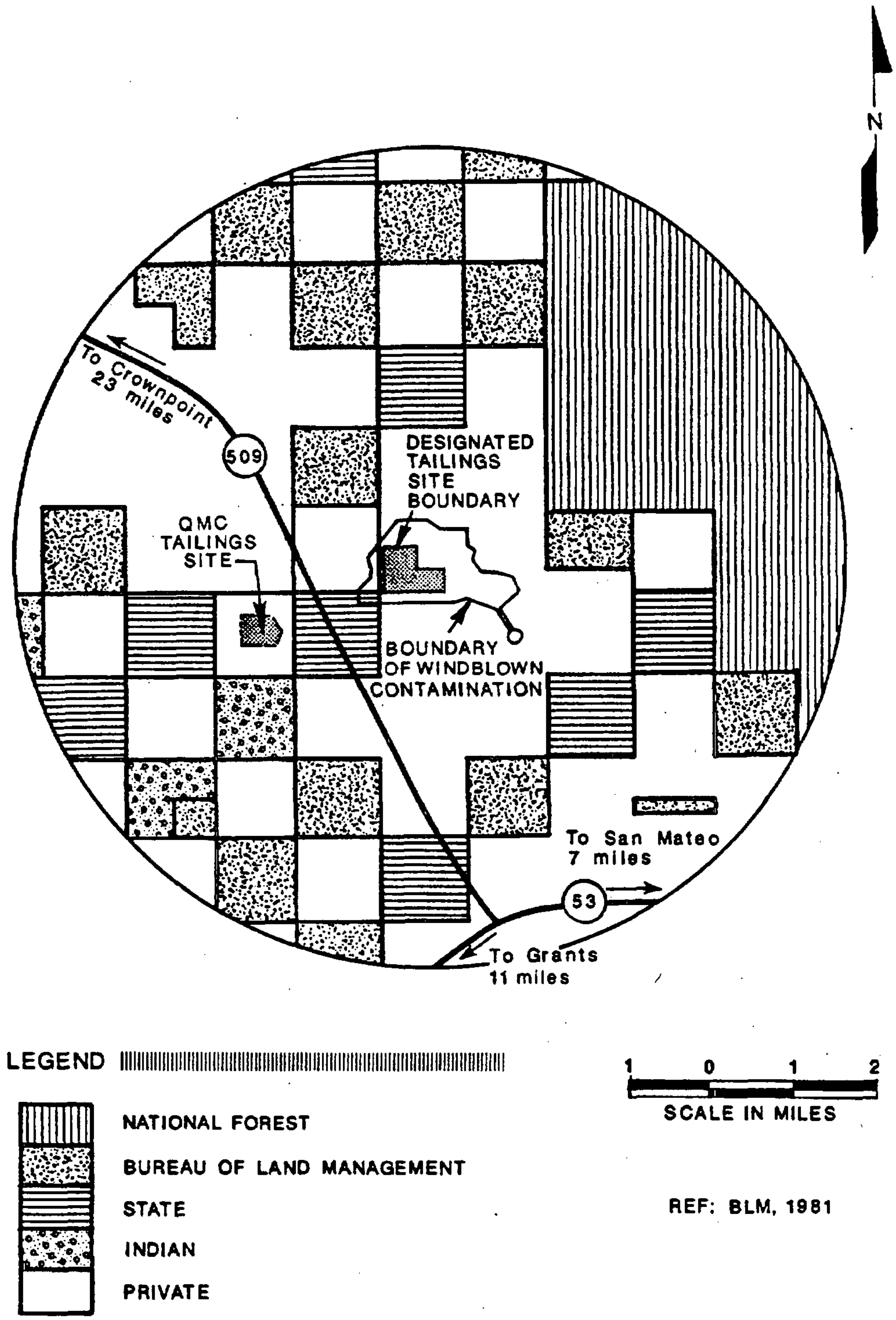


FIGURE 5.1
LAND OWNERSHIP WITHIN FIVE MILES OF THE AMBROSIA LAKE TAILINGS SITE

directions around the Ambrosia Lake tailings site (Figure 5.1). Within the CRA, some of the privately owned land consists of both inactive and abandoned mining operations. The Quivira Mining Company tailings site is located approximately two miles southwest of the Ambrosia Lake site. The inactive Ann Lee Mine No. 1 is located immediately northeast of the Ambrosia Lake site. Other mines within a five-mile radius of the site include the Homestake-New Mexico Partners Mine to the southwest, the Section 33 Mine to the south, the Sandstone Mine to the southeast, the Section 27 Mine to the east, the Kermac Mine No. 30 to the west, and Mine No. 17 to the northwest (DOE, 1987) (see Figure D.8.9 in Appendix D).

5.6 FUTURE LAND USE

The area within the CRA has been recently dominated by the uranium mining and milling industry, and historically by low-density grazing. It is doubtful that a significant expansion of grazing will occur since the area is semiarid, the soils are poor, and the rangeland is overgrazed, and both surface water and high-quality shallow groundwater resources are limited.

The future of the active uranium mines and mills of the area is directly related to trends in the uranium market. Inactive mining and milling areas could become active if there is a resurgence in the market value of uranium ore. Also, future development of other lands for the uranium mining industry could occur given an adequate market.

6.0 GROUNDWATER USE AND PROXIMITY

6.1 EXISTING USE

Groundwater is the primary source of water in the Ambrosia Lake area. Current groundwater consumption is approaching pre-1955 use due to the decline of the uranium mining industry. The principal groundwater uses in the Ambrosia Lake area are for the uranium mining industry, and for domestic and stock watering purposes (DOE, 1987).

The uranium mining industry has been the principal user of groundwater since the mid-1950s in the Ambrosia Lake area. The Westwater Canyon Member of the Morrison Formation is the ore-bearing aquifer in the Ambrosia Lake mining district. Beginning in the mid-1950s, uranium mine dewatering withdrew large amounts of groundwater from the Westwater Canyon Member to facilitate uranium ore removal. Pumpage from mines in the Ambrosia Lake area ranged from eight to 13 million gallons per day (NMEID, 1980). Potentiometric levels were lowered hundreds of feet in the eastern Ambrosia Lake area after 20 years of pumping.

At the current time, many of the uranium mines in the Ambrosia Lake area have ceased operations due to the decline in domestic uranium market. Many of the mines are still being dewatered and some of this water is being reinjected for a solution recovery of uranium from the previously mined areas (see additional discussion on water use in Section D.8.9 in Appendix D).

The town of San Mateo, 15 miles southeast of the Ambrosia Lake site, is the nearest municipality operating a public water supply. In the former town of Ambrosia Lake, approximately two miles northwest of the site, four private wells are completed in the Westwater Canyon Member and the alluvium along San Mateo Creek, and supply water for homes and trailers. There are no domestic wells completed in any of the Tres Hermanos Sandstones or within the alluvium in the Ambrosia Lake valley, since these hydrostratigraphic units do not yield an adequate supply of groundwater of acceptable quality.

One active stock well, one domestic well, and one well with an ~~unknown use (probably for stock) are within the CRA (Table 6.1). One stock well is completed in the San Andres Limestone at a depth in excess of 3000 feet.~~

There is no present or historical irrigation within the Ambrosia Lake valley, and no demand is anticipated due to poor soils and limited groundwater of good quality (DOE, 1987).

6.2 POTENTIAL USE

If uranium production becomes economically viable in the future, groundwater use for industrial purposes would likely be similar in nature and extent as during the 1950s through the 1970s. Future development of groundwater resources for non-mining (domestic and stock) use in the

Table 6.1 Records of domestic and stock wells within the CRA

Owner or well name[a]	Principal aquifer[b]	Location no.	Total depth(ft)	Use
Phil Harris	S	14.9.17	>3000	Stock
Berryhill	JM	14.9.18.234	800	Domestic
Berryhill	JM	14.9.32.314	550	Stock (?)

a Does not include known abandoned wells.
b JM = Westwater Canyon Member, Morrison Formation; S = San Andres Limestone.
Ref. Brod and Stone, 1981; Marquez, 1985; Baughman, 1985; Wohlenberg, 1989.

Ambrosia Lake area does not seem likely. The State of New Mexico initiated a permit requirement for domestic wells in May 1976. Since the initiation of the permit requirement, no permits have been issued for domestic wells within five miles of the Ambrosia Lake tailings site (Wohlenberg, 1989). As previously stated, many of the wells in the Ambrosia Lake valley have been abandoned. Dewatering of the aquifers for mining operations has lowered the potentiometric levels hundreds of feet in the Ambrosia Lake area. In addition, there are no domestic wells completed in any of the shallow aquifers, such as the Tres Hermanos Sandstones or within the alluvium in the Ambrosia Lake valley.

Future development of groundwater for livestock watering is also expected to be very minimal. Area lands are used for low-density grazing, with some water needs currently met by the use of surface water collected from ephemeral streams. Although there are two wells presently used for livestock within the CRA, they are completed at depths in excess of 500 feet. Additional development of groundwater for stock watering purposes is expected to be minimal. This is due to the lack of adequate forage to support additional livestock.

7.0 GROUNDWATER CLASSIFICATION

7.1 FEDERAL

The EPA has developed final-draft guidelines for groundwater classification (EPA, 1986), which the DOE has adopted for determination of Class III groundwaters (DOE, 1989a). The classification system, which is related to use and quality, is based on three classes of water, Classes I, II and III. Drinking water is considered to be the highest beneficial use of groundwater.

Class I waters are special waters that require protection. These aquifers are highly vulnerable to contamination and are irreplaceable sources of water serving substantial populations, and/or are ecologically vital.

Class II waters consist of aquifers that are current or potential sources of drinking water. The EPA has subdivided Class II waters into Class IIA and Class IIB. Class IIA waters are current sources of drinking water and Class IIB are potential sources of drinking water.

Class III (limited use) groundwaters are neither current nor potential sources of drinking water. Groundwater is Class III if it meets one or more of the following criteria (40 CFR 192.11(e)) (EPA, 1987):

- The total dissolved solids (TDS) concentration exceeds 10,000 milligrams per liter (mg/l).
- The water is not a current or potential source of drinking water due to widespread ambient contamination caused by natural conditions or by human activity, excluding contributions from uranium milling, and the water cannot be cleaned up using methods reasonably employed by public water supply systems.
- The aquifer is incapable of producing more than 150 gallons per day for a sustained period of time.

The EPA has subdivided Class III groundwater into two categories that relate to the degree of interconnection. Class IIIA waters have an intermediate to high degree of interconnection to adjacent surface waters or groundwaters. Class IIIB groundwaters have a low degree of interconnection. Groundwaters with insufficient yield (less than 150 gallons per day sustained yield) are classified as Class IIIA.

As discussed in Section D.8.4, the uppermost aquifer at the Ambrosia Lake site is incapable of producing more than 150 gallons per day. Therefore, the alluvial system constitutes a Class III groundwater.

7.2 STATE OF NEW MEXICO

A groundwater classification system has not been developed in New Mexico, although the State of New Mexico does provide protection of groundwater resources through implementation and enforcement of the New Mexico Water Quality Act (WQCC, 1987), the New Mexico Water Quality Standards (WQCC, 1981), and the New Mexico Water Quality Regulations (WQCC, 1986). All aspects of groundwater protection are administered by the New Mexico Water Quality Control Commission (WQCC).

The purpose of the WQCC groundwater regulations is to protect all groundwaters of the state which have existing concentrations of total dissolved solids of 10,000 mg/l or less. Groundwater protection is for present and potential future use as domestic and agricultural water supply, and for protection of those segments of surface waters which are gaining because of groundwater inflow (WQCC, 1986).

The State of New Mexico has adopted some of the Federal maximum concentration limits (MCLs) for a few of the chemicals regulated under the Safe Drinking Water Act (ILENR, 1988).

The State of New Mexico has also made provisions for assessing existing groundwater quality in groundwater discharge plans submitted by the active mills in the Ambrosia Lake area. The WQCC regulations (WQCC, 1986), state that "if the existing concentration of any water contaminant in ground water is in conformance with the standard (Section 3-103, WQCC 1986), degradation of the ground water up to the limit of the standard will be allowed." In the situation where "the existing concentration of any contaminant in ground water exceeds the standard of Section 3-103, no degradation of the ground water beyond the existing concentration will be allowed" (WQCC, 1986). The numerical groundwater standards are established at the point of present or foreseeable groundwater use (Bostick, 1986).

The state and Federal groundwater quality regulations are listed in Table D.10.3. of Appendix D.

8.0 SURFACE WATER AND PROXIMITY

The Ambrosia Lake tailings site lies in the drainage basin of Arroyo del Puerto, an intermittent tributary of San Mateo Creek (see Figure D.10.2 of Appendix D). The water quality of Arroyo del Puerto and downstream sections of San Mateo Creek is affected by seepage from the Quivira Mine Company tailings ponds and mine water discharges from the Ambrosia Lake area (FBDU, 1983; Gallaher and Goad, 1981; NMEID, 1980). Perennial flow had been sustained in Arroyo del Puerto from the late 1950s until 1980 by mine water discharge (Brod and Stone, 1981). Arroyo del Puerto has since reverted to an intermittent stream due to the reduction in mining activity. The flow in Arroyo del Puerto is generally lost to channel infiltration and evapotranspiration a short distance above its confluence with San Mateo Creek, about five miles south of the site.

Two unnamed drainage channels are also present near the site (see Figure D.10.1 in Appendix D). These channels originate northeast of the tailings pile. The northern ephemeral stream drains an area of approximately 1550 acres and terminates northern of the existing tailings pile. The northern ephemeral stream shows no indication of draining to Arroyo del Puerto. The eastern ephemeral stream drains approximately 450 acres. Runoff from the eastern ephemeral stream is collected in three stock tanks upstream of the tailings site or is intercepted just east of the site and is diverted into Voght tank, a stock watering pond. The eastern ephemeral stream is the only one of the two drainage channel that is used for livestock watering. Overflow from the Voght tank enters a drainage channel which discharges into Arroyo del Puerto approximately 2.5 miles south of the site (DOE, 1987).

9.0 SURFACE WATER CLASSIFICATION

The waters of the state are defined in accordance with the New Mexico Water Quality Standards, as established under the New Mexico Water Quality Act. Water quality standards and regulations are administered by the WQCC. The water quality standards for interstate and intrastate streams in New Mexico define the designated uses of surface water and establish general standards and area-specific standards for maintaining water quality. Since the only use of surface water in the area is for stock watering purposes, no attempt at surface water classification has been made for this discussion.

10.0 POTENTIAL DEVELOPMENT OF WATER RESOURCES

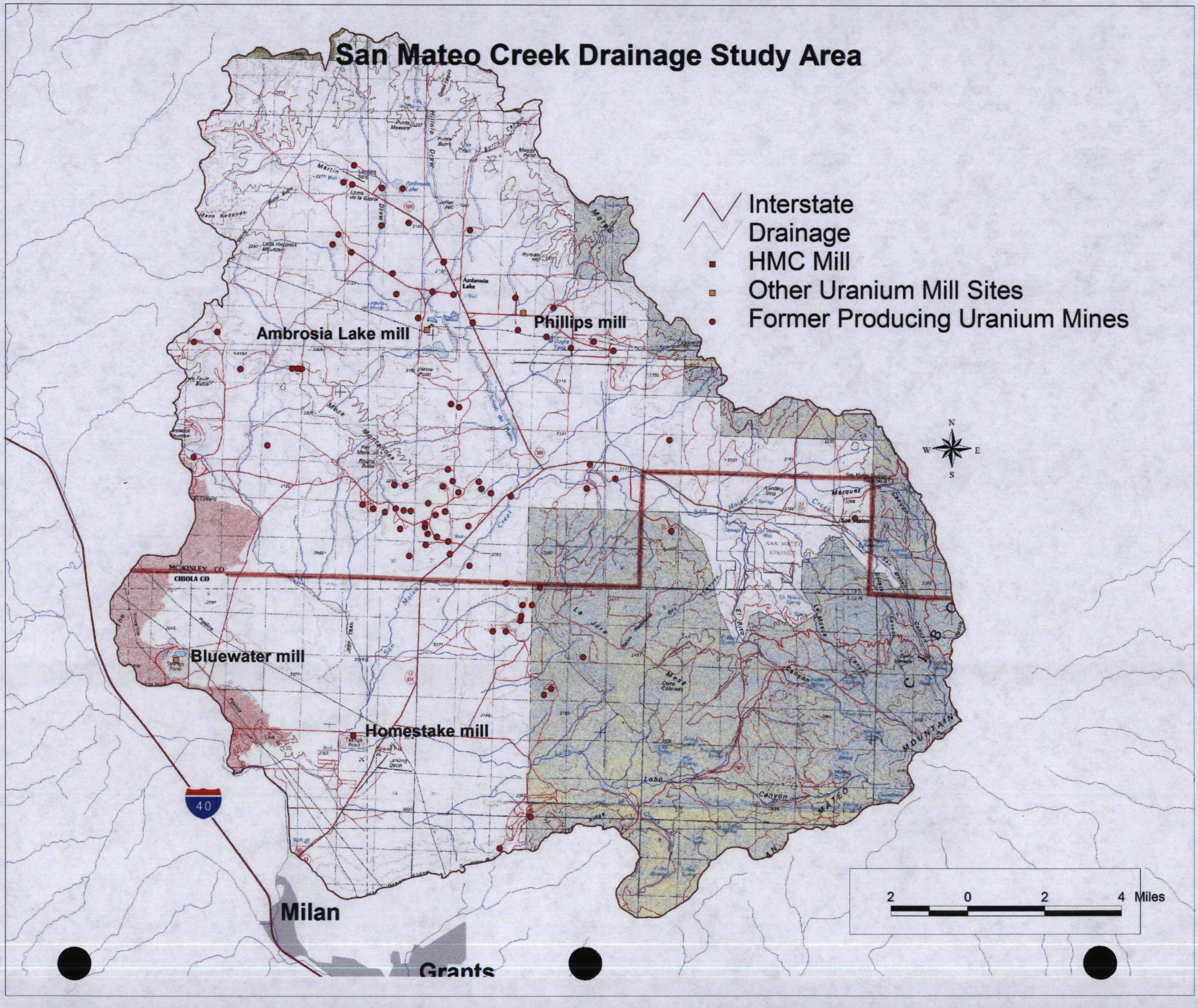
Future development of the limited groundwater resources in the Ambrosia Lake area is dependent upon the uranium mining industry. Development and large-scale use of water resources in the area has coincided with the uranium mining industry, which began in the 1950s. With the collapse of the mining and milling activities, the majority of mines and support operations have closed. Businesses in the Grants-Milan area that supported the mining industry have also been adversely affected. New mining and milling activities could stimulate a development of the groundwater resources similar to the past 20-year uranium mining period in the Grants area. If this occurs, further degradation of the groundwater quality in the area may occur due to mine dewaterings and the like.

Prior to the beginning of mining in the 1950s, there was little development in the Ambrosia Lake area and limited use of groundwater. The 20-year period of uranium mining and milling activity stimulated the temporary development of the Ambrosia Lake valley, substantially degraded the water quality, and reduced the quantity of groundwater resources. Future development of groundwater resources in the area is expected to be even more limited than the minimal development which occurred prior to mining. Low density grazing will continue in the Ambrosia Lake area. However, groundwater use for stock watering purposes is not expected to increase much above current levels. If additional stock water is required, it would be developed from the deeper aquifers.

There are no permanent natural surface-water bodies within the CRA. Arroyo del Puerto is not a reliable supply of surface water since it is an intermittent stream because the flow is generally lost to channel infiltration and evapotranspiration. The unnamed eastern ephemeral stream will likely continue to be used for livestock watering. There is the potential for similar development of the unnamed northern ephemeral stream for livestock watering.

REFERENCES

9-13



San Mateo Creek Drainage Study Area
Interstate
Drainage
HMC Mill
Other Uranium Mill Sites
Former Producing Uranium Mines
Ambrosia Lake mill
Phillips mill
Bluewater mill
Homestake mill
Milan
Grants
MC KINLEY CO
CIBOLA CO
40
N
S
E
W
2
0
2
4
Miles

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DOS LOMAS QUADRANGLE
NEW MEXICO
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography from aerial photographs by photogrammetric methods
Aerial photographs taken 1956 Field check 1957

Polyconic projection. 1927 North American datum
10,000-foot grid based on New Mexico coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

Certain land lines omitted in T. 13 N. R. 9 W. because of alleged fraud or defects in the surveys

To place on the predicted North American Datum 1983 move the projection lines 55 meters east as shown by dashed corner ticks

UTM GRID AND 1980 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

There may be private inholdings within the boundaries of the National or State reservations shown on this map

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

Revisions shown in purple compiled from aerial photographs taken 1978 and other source data. This information not field checked. Map edited 1980

ROAD CLASSIFICATION
Medium-duty Light-duty
Unimproved dirt
State Route

DOS LOMAS, N. MEX.
N3515—W10745/7.5

1957
PHOTOREVISED 1980
DMA 4454 IV SE SERIES V881

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

AMBROSIA LAKE QUADRANGLE
NEW MEXICO-McKINLEY CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography from aerial photographs by photogrammetric methods
Aerial photographs taken 1956. Field check 1957

Polyconic projection. 1927 North American datum
10,000-foot grid based on New Mexico coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

Dashed land lines indicate approximate locations
Land lines are omitted in Ts. 13 and 15 N.-R. 9 W. and in parts of T. 14 N.-Rs. 9 and 10 W. because of alleged fraud or defects in the surveys

To place on the predicted North American Datum 1983 move the projection lines 55 meters east as shown by dashed corner ticks

UTM GRID AND 1980 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

There may be private inholdings within the boundaries of the National or State reservations shown on this map

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

NEW MEXICO
QUADRANGLE LOCATION

Revisions shown in purple compiled from aerial photographs taken 1978 and other source data. This information not field checked. Map edited 1980

ROAD CLASSIFICATION
Medium-duty Light-duty
Unimproved dirt
State Route

AMBROSIA LAKE, N. MEX.
N3522.5—W10745/7.5

1957
PHOTOREVISED 1980
DMA 4454 IV NE—SERIES V881

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SAN LUCAS DAM QUADRANGLE
NEW MEXICO-MCKINLEY CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography by photogrammetric methods from aerial photographs taken 1956 and 1958. Field checked 1963

Polyconic projection. 1927 North American datum
10,000-foot grid based on New Mexico coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

Fine red dashed lines indicate selected fence lines

Certain land lines are omitted because of insufficient data

Areas covered by dashed light blue pattern are subject to controlled inundation

There may be private inholdings within the boundaries of the National or State reservations shown on this map

UTM GRID AND 1980 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

To place on the predicted North American Datum 1983 move the projection lines 55 meters east as shown by dashed corner ticks

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

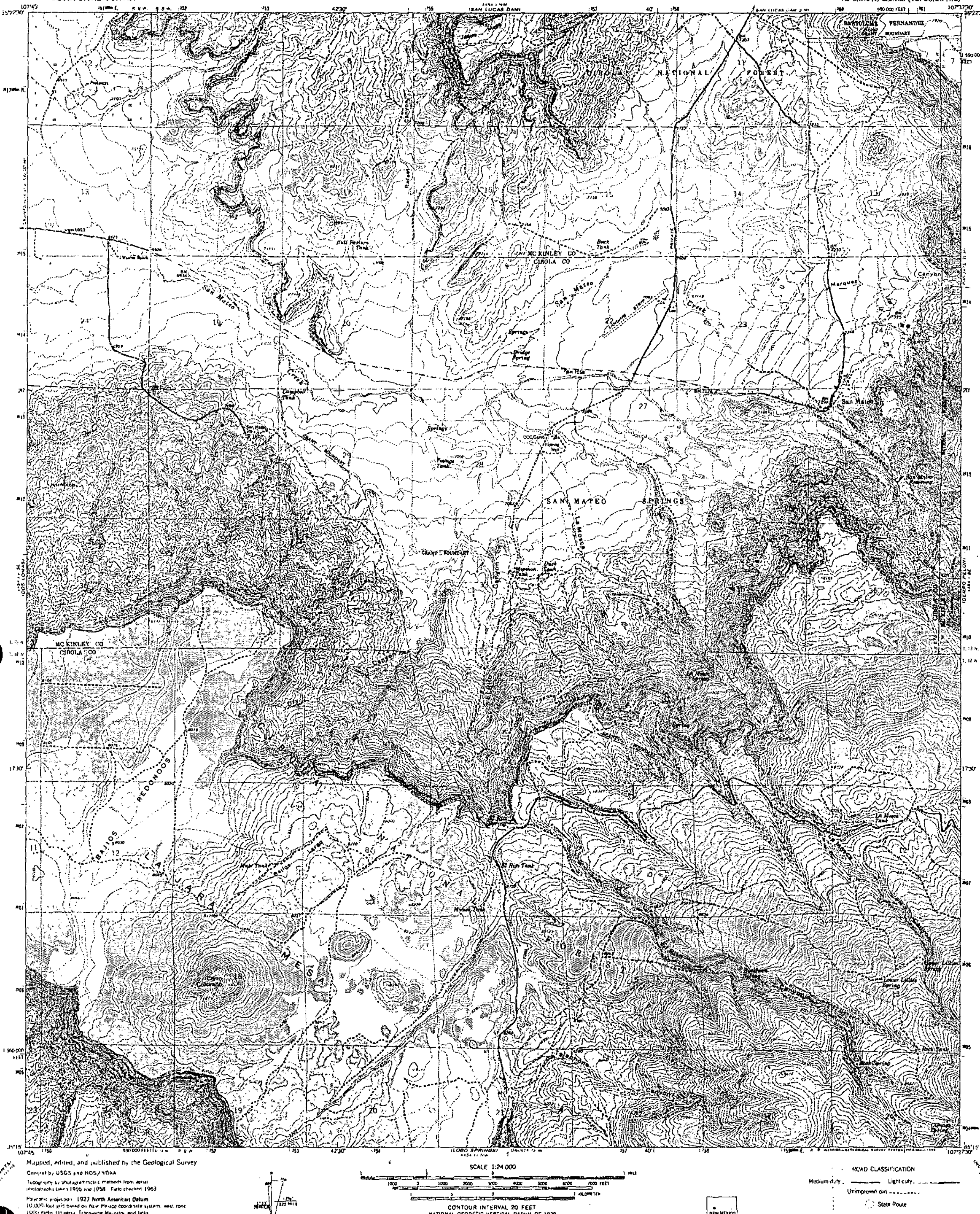
ROAD CLASSIFICATION
Light-duty ——— Unimproved dirt - - - - -

SAN LUCAS DAM, N. MEX.
N3522.5-W10737.5/7.5

1963
DMA 4434 I NW-SERIES V881

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SAN MATEO QUADRANGLE
NEW MEXICO
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography by photogrammetric methods from aerial photographs taken 1956 and 1958. Field checked 1963

Polyconic projection. 1927 North American Datum
10,000-foot grid based on New Mexico coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

Fine red dashed lines indicate selected fence lines

To place on the predicted North American Datum 1983 move the projection lines 55 meters east as shown by dashed corner ticks

There may be private inholdings within the boundaries of the National or State reservations shown on this map

UTM GRID AND 1981 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

Revisions shown in purple compiled from aerial photographs taken 1978 and other source data. This information not field checked. Map edited 1981

ROAD CLASSIFICATION
Medium-duty ______ Light-duty ______
Unimproved dirt ------
State Route

SAN MATEO, N. MEX.
35107-C6-TF-024
1963
PHOTOREVISED 1981
DMA 4454 I SW-SERIES V881

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SAN MATEO QUADRANGLE
NEW MEXICO
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography by photogrammetric methods from aerial photographs taken 1956 and 1958 Field checked 1963

Polyconic projection. 1927 North American Datum
10,000-foot grid based on New Mexico coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

Fine red dashed lines indicate selected fence lines

To place on the predicted North American Datum 1983 move the projection lines 55 meters east as shown by dashed corner ticks

There may be private inholdings within the boundaries of the National or State reservations shown on this map

UTM GRID AND 1981 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
Medium-duty Light-duty
Unimproved dirt
State Route

NEW MEXICO
QUADRANGLE LOCATION

Revisions shown in purple compiled from aerial photographs taken 1978 and other source data. This information not field checked. Map edited 1981

SAN MATEO, N. MEX.
35107-C6-TF-024
1963
PHOTOREVISED 1981
DMA 4454 I SW-SERIES V881

A. URANIUM MILL TAILINGS RADIATION CONTROL ACT OF 1978, AS AMENDED

TABLE OF CONTENTS

B. PERTINENT PROVISIONS OF THE ENERGY POLICY ACT OF 1992

* * * * *

C. NATIONAL DEFENSE AUTHORIZATION FISCAL YEAR 2001

A. URANIUM MILL TAILINGS RADIATION CONTROL ACT OF 1978, AS AMENDED

Public Law 95-604 92 Stat. 3021

November 8, 1978

An Act

Sec. 1. Short Title and Table of Contents

This Act may be cited as the "Uranium Mill Tailings Radiation Control Act of 1978." (TOC not duplicated here.)

Sec. 2. Findings and Purposes

42 USC 7901. (a) The Congress finds that uranium mill tailings located at active and inactive mill operations may pose a potential and significant radiation health hazard to the public, and that the protection of the public health, safety, and welfare and the regulation of interstate commerce require that every reasonable effort be made to provide for the stabilization, disposal, and control in a safe and environmentally sound manner of such tailings in order to prevent or minimize radon diffusion into the environment and to prevent or minimize other environmental hazards from such tailings.

(b) The purposes of this Act are to provide–

(1) in cooperation with the interested States, Indian tribes, and the persons who own or control inactive mill tailings sites, a program of assessment and remedial action at such sites, including, where appropriate, the reprocessing of tailings to extract residual uranium and other mineral values where practicable, in order to stabilize and control such tailings in a safe and environmentally sound manner and to minimize or eliminate radiation health hazards to the public, and

(2) a program to regulate mill tailings during uranium or thorium ore processing at active mill operations and after termination of such operations in order to stabilize and control such tailings in a safe and environmentally sound manner and to minimize or eliminate radiation health hazards to the public.

TITLE I–REMEDIAL ACTION PROGRAM

Sec. 101. Definitions

42 USC 7911. For purposes of this title–

(1) The term "Secretary" means the Secretary of Energy.

(2) The term "Commission" means the Nuclear Regulatory Commission.

(3) The term "Administrator" means the Administrator of the Environmental Protection Agency.

(4) The term "Indian tribe" means any tribe, band, clan, group, pueblo, or community of Indians recognized as eligible for services provided by the Secretary of the Interior to Indians.

(5) The term "person" means any individual association, partnership, corporation, firm, joint venture, trust, government entity, and any other entity, except that such term does not include any Indian or Indian tribe.

(6) The term "processing site" means–
(A) any site, including the mill, containing residual radioactive materials at which all or substantially all of the uranium was produced for sale to any Federal agency prior to January 1, 1971 under a contract with any Federal agency, except in the case of a site at or near Slick Rock, Colorado, unless–
(i) such site was owned or controlled as of January 1, 1978, or is thereafter owned or controlled by any Federal agency, or
(ii) a license (issued by the Commission or its predecessor agency under the Atomic Energy Act of 1954 or by a State as permitted under section 274 of such Act) for the production at such site of any uranium or thorium product derived from ores is in effect on January 1, 1978, or is issued or renewed after such date; and
(B) any other real property or improvement thereon which–
(i) is in the vicinity of such site, and
42 USC 2011 note. 42 USC 2021. (ii) is determined by the Secretary, in consultation with the Commission, to be contaminated with residual radioactive materials derived from such site.

Any ownership or control of an area by a Federal agency which is acquired pursuant to a cooperative agreement under this title shall not be treated as ownership or control by such agency for purposes of subparagraph (A)(i). A license for the production of any uranium product from residual radioactive materials shall not be treated as a license for production from ores within the meaning of subparagraph (A)(ii) if such production is in accordance with section 108(b).

(7) The term "residual radioactive material" means–
(A) waste (which the Secretary determines to be radioactive) in the form of tailings resulting from the processing of ores for the extraction of uranium and other valuable constituents of the ores; and
(B) other waste (which the Secretary determines to be radioactive) at a processing site which relate to such processing, including any residual stock of unprocessed ores or low-grade materials.

(8) The term "tailings" means the remaining portion of a metal-bearing ore after some or all of such metal, such as uranium, has been extracted.

(9) The term "Federal agency" includes any executive agency as defined in section 105 of title 5 of the United States Code.

(10) The term "United States" means the 48 contiguous States and Alaska, Hawaii, Puerto Rico, the District of Columbia, and the territories and possessions of the United States.

Sec. 102. Designation of Processing Sites

42 USC 7912. (a)(1) As soon as practicable, but no later than one year after enactment of this Act, the Secretary shall designate processing sites at or near the following locations:

Salt Lake City, Utah
Green River, Utah
Mexican Hat, Utah
Durango, Colorado
Grand Junction, Colorado

Rifle, Colorado (two sites)
Gunnison, Colorado
Naturita, Colorado
Maybell, Colorado
Slick Rock, Colorado (two sites)
Shiprock, New Mexico
Ambrosia Lake, New Mexico
Riverton, Wyoming
Converse County, Wyoming
Lakeview, Oregon
Falls City, Texas
Tuba City, Arizona
Monument Valley, Arizona
Lowman, Idaho
Canonsburg, Pennsylvania

Remedial action.

Subject to the provisions of this title, the Secretary shall complete remedial action at the above listed sites before his authority terminates under this title. The Secretary shall within one year of the date of enactment of this Act also designate all other processing sites within the United States which he determines requires remedial action to carry out the purposes of this title. In making such designation, the Secretary shall consult with the Administrator, the Commission, and the affected States, and in the case of Indian lands, the appropriate Indian tribe and the Secretary of the Interior.

(2) As part of his designation under this subsection, the Secretary, in consultation with the Commission, shall determine the boundaries of each such site.

86 Stat. 222.

(3) No site or structure with respect to which remedial action is authorized under Public Law 92-314 in Grand Junction, Colorado, may be designated by the Secretary as a processing site under this section.

Health hazard assessment.

(b) Within one year from the date of the enactment of this Act, the Secretary shall assess the potential health hazard to the public from the residual radioactive materials at designated processing sites. Based upon such assessment, the secretary shall, within such one year period, establish priorities for carrying out remedial action at each such site. In establishing such priorities, the Secretary shall rely primarily on the advice of the Administrator.

Notification.

(c) Within thirty days after making designations of processing sites and establishing the priorities for such sites under this section, the Secretary shall notify the Governor of each affected State, and where appropriate, the Indian tribes and the Secretary of the Interior.

(d) The designations made, and priorities established, by the Secretary under this section shall be final and not be subject to judicial review.

(e)(1) The designation of processing sites within one year after enactment under this section shall include, to the maximum extent practicable, the areas referred to in section 101(6)(B).

(2) Notwithstanding the one year limitation contained in this section, the Secretary may, after such one year period, include any areas described in section 101(6)(B) as part of a processing site designated under this section if he determines such inclusion to be appropriate to carry out the purposes of this title.

42 USC 7911. (3) The Secretary shall designate as a processing site within the meaning of section 101(6) any real property, or improvements thereon, in Edgemont, South Dakota, that–

(A) is in the vicinity of the Tennessee Valley Authority uranium mill site at Edgemont (but not including such site), and

(B) is determined by the Secretary to be contaminated with residual radioactive materials.

(f)(1) DESIGNATION. Notwithstanding any other provision of law, the Moab uranium milling site (referred to in this subsection as the "Moab site") located approximately three miles northwest of Moab, Utah, and identified in the Final Environmental Impact Statement issued by the Nuclear Regulatory Commission in March 1996 in conjunction with Source Materials License No. SUA-917, is designated as a processing site.

(2) APPLICABILITY. This title applies to the Moab site in the same manner and to the same extent as to other processing sites designated under subsection (a), except that–

(A) sections 103, 104(b), 107(a), 112(a), and 115(a) of this title shall not apply; and

(B) a reference in this title to the date of the enactment of this Act shall be treated as a reference to the date of the enactment of this subsection [enacted October 30, 2000].

(3) REMEDIATION. Subject to the availability of appropriations for this purpose, the Secretary shall conduct remediation at the Moab site in a safe and environmentally sound manner that takes into consideration the remedial action plan prepared pursuant to section 3405(i) of the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999 (10 USC 7420 note; Public Law 105-261, including–

(A) ground water restoration; and

(B) the removal, to a site in the State of Utah, for permanent disposition and any necessary stabilization, of residual radioactive material and other contaminated material from the Moab site and the floodplain of the Colorado River.[1]

42 USC 7917. In making the designation under this paragraph, the Secretary shall consult with the Administrator, the Commission and the State of South Dakota. The provisions of this title shall apply to the site so designated in the same manner and to the same extent as to the sites designated under subsection (a) except that, in applying such provisions to such site, any reference in this title to the date of enactment of this Act shall be treated as a reference to the date of the enactment of this paragraph and in determining the State share under section 107 of the costs of remedial action, there shall be credited to the State, expenditures made by the State prior to the date of the enactment of this paragraph which the Secretary

[1]As amended, Public Law 106-398, sec. 1, (114 Stat. 1654), October 30, 2000.

determines would have been made by the State or the United States in carrying out the requirements of this title.[2]

Sec. 103. State Cooperative Agreements

42 USC 7913.

(a) After notifying a State of the designation referred to in section 102 of this title, the Secretary subject to section 113, is authorized to enter into cooperative agreement with such State to perform remedial actions at each designated processing site in such State (other than a site location on Indian lands referred to in section 105). The Secretary shall, to the greatest extent practicable, enter into such agreements and carry out such remedial actions in accordance with the priorities established by him under section 102. The Secretary shall commence preparations for cooperative agreements with respect to each designated processing site as promptly as practicable following the designation of each site.

Terms and Conditions.

(b) Each cooperative agreement under this section shall contain such terms and conditions as the Secretary deems appropriate and consistent with the purposes of this Act, including, but not limited to, a limitation on the use of Federal assistance to those costs which are directly required to complete the remedial action selected pursuant to section 108.

Written consent.

(c)(1) Except where the State is required to acquire the processing site as provided in subsection (a) of section 104, each cooperative agreement with a State under section 103 shall provide that the State shall obtain, in a form prescribed by the Secretary, written consent from any person holding any record interest in the designated processing site for the Secretary or any person designated by him to perform remedial action at such site.

Waiver.

(2) Such written consent shall include a waiver by each such person on behalf of himself, herself, his heirs, successors, and assigns–

(A) releasing the United States of any liability or claims thereof by such person, his heirs, successors, and assigns concerning such remedial action, and

(B) holding the United States harmless against any claim by such person on behalf of himself, his heirs, successors, or assigns arising out of the performance of any remedial action.

(d) Each cooperative agreement under this section shall require the State to assure that the Secretary, the Commission, and the Administrator and their authorized representatives have a permanent right of entry at any time to inspect the processing site and the site provided pursuant to section 104(b)(1) in furtherance of the provisions of this title and to carry out such agreement and enforce this Act and any rules prescribed under this Act. Such right of entry under this section or section 106 into an area described in section 101(6)(B) shall terminate on completion of the remedial action, as determined by the Secretary.

(e) Each agreement under this section shall take effect only upon the concurrence of the Commission with the terms and conditions thereof.

(f) The Secretary may, in any cooperative agreement enter into this section or section 105, provide for reimbursement of the actual costs, as determined by the Secretary, of any remedial action performed with respect to so much of a designated processing site as is described in section 101(6)(B). Such reimbursement shall be made only to a property owner of record at the time such remedial action was undertaken and only

[2]Public Law 97-415 (96 Stat. 2067)(1983), added (3) to sec. 102(e).

Electronic Code of Federal Regulations
e-CFR™

e-CFR Data is current as of May 13, 2008

Title 40: Protection of Environment

Browse Previous | Browse Next

PART 192—HEALTH AND ENVIRONMENTAL PROTECTION STANDARDS FOR URANIUM AND THORIUM MILL TAILINGS

Section Contents

Authority: Sec. 275 of the Atomic Energy Act of 1954, 42 U.S.C. 2022, as added by the Uranium Mill Tailings Radiation Control Act of 1978, Pub. L. 95–604, as amended.

Source: 48 FR 602, Jan. 5, 1983, unless otherwise noted.

Subpart A—Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites

top

§ 192.00 Applicability.

top

This subpart applies to the control of residual radioactive material at designated processing or depository sites under section 108 of the Uranium Mill Tailings Radiation Control Act of 1978 (henceforth designated "the Act"), and to restoration of such sites following any use of subsurface minerals under section 104(h) of the Act.

§ 192.01 Definitions.

top

(a) *Residual radioactive material* means:

(1) Waste (which the Secretary determines to be radioactive) in the form of tailings resulting from the processing of ores for the extraction of uranium and other valuable constituents of the ores; and

(2) Other wastes (which the Secretary determines to be radioactive) at a processing site which relate to such processing, including any residual stock of unprocessed ores or low-grade materials.

(b) *Remedial* action means any action performed under section 108 of the Act.

(c) *Control* means any remedial action intended to stabilize, inhibit future misuse of, or reduce emissions or effluents from residual radioactive materials.

(d) *Disposal site* means the region within the smallest perimeter of residual radioactive material (excluding cover materials) following completion of control activities.

(e) *Depository site* means a site (other than a processing site) selected under Section 104(b) or 105(b) of the Act.

(f) *Curie* (Ci) means the amount of radioactive material that produces 37 billion nuclear transformation per second. One picocurie (pCi) = 10^{-12}Ci.

(g) *Act* means the Uranium Mill Tailings Radiation Control Act of 1978, as amended.

(h) *Administrator* means the Administrator of the Environmental Protection Agency.

(i) *Secretary* means the Secretary of Energy.

(j) *Commission* means the Nuclear Regulatory Commission.

(k) Indian *tribe* means any tribe, band, clan, group, pueblo, or community of Indians recognized as eligible for services provided by the Secretary of the Interior to Indians.

(l) *Processing site* means:

(1) Any site, including the mill, designated by the Secretary under Section 102(a)(1) of the Act; and

(2) Any other real property or improvement thereon which is in the vicinity of such site, and is determined by the Secretary, in consultation with the Commission, to be contaminated with residual radioactive materials derived from such site.

(m) *Tailings* means the remaining portion of a metal-bearing ore after some or all of such metal, such as uranium, has been extracted.

(n) *Disposal period* means the period of time beginning March 7, 1983 and ending with the completion of all subpart A requirements specified under a plan for remedial action except those specified in §192.03 and §192.04.

(o) *Plan for remedial action* means a written plan (or plans) for disposal and cleanup of residual radioactive materials associated with a processing site that incorporates the results of site characterization studies, environmental assessments or impact statements, and engineering assessments so as to satisfy the requirements of subparts A and B of this part. The plan(s) shall be developed in accordance with the provisions of Section 108(a) of the Act with the concurrence of the Commission and in consultation, as appropriate, with the Indian Tribe and the Secretary of Interior.

(p) *Post-disposal period* means the period of time beginning immediately after the disposal period and ending at termination of the monitoring period established under §192.03.

(q) *Groundwater* means water below the ground surface in a zone of saturation.

(r) *Underground source of drinking water* means an aquifer or its portion:

(1) Which supplies any public water system as defined in §141.2 of this chapter; or

(ii) Which contains a sufficient quantity of groundwater to supply a public water system; and

(A) Currently supplies drinking water for human consumption; or

(B) Contains fewer than 10,000 mg/l total dissolved solids; and

(2) Which is not an exempted aquifer as defined in §144.7 of this chapter.

[48 FR 602, Jan. 5, 1983, as amended at 60 FR 2865, Jan. 11, 1995]

§ 192.02 Standards.

top

Control of residual radioactive materials and their listed constituents shall be designed[1] to:

[1] Because the standard applies to design, monitoring after disposal is not required to demonstrate compliance with respect to §192.02(a) and (b).

(a) Be effective for up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years, and,

(b) Provide reasonable assurance that releases of radon-222 from residual radioactive material to the atmosphere will not:

(1) Exceed an average[2] release rate of 20 picocuries per square meter per second, or

[2] This average shall apply over the entire surface of the disposal site and over at least a one-year period. Radon will come from both residual radioactive materials and from materials

covering them. Radon emissions from the covering materials should be estimated as part of developing a remedial action plan for each site. The standard, however, applies only to emissions from residual radioactive materials to the atmosphere.

(2) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter.

(c) Provide reasonable assurance of conformance with the following groundwater protection provisions:

(1) The Secretary shall, on a site-specific basis, determine which of the constituents listed in Appendix I to Part 192 are present in or reasonably derived from residual radioactive materials and shall establish a monitoring program adequate to determine background levels of each such constituent in groundwater at each disposal site.

(2) The Secretary shall comply with conditions specified in a plan for remedial action which includes engineering specifications for a system of disposal designed to ensure that constituents identified under paragraph (c)(1) of this section entering the groundwater from a depository site (or a processing site, if residual radioactive materials are retained on the site) will not exceed the concentration limits established under paragraph (c)(3) of this section (or the supplemental standards established under §192.22) *in the uppermost aquifer underlying the site beyond the point of compliance established under paragraph (c)(4) of this section.*

(3) Concentration limits:

(i) Concentration limits shall be determined in the groundwater for listed constituents identified under paragraph (c)(1) of this section. The concentration of a listed constituent in groundwater must not exceed:

(A) The background level of that constituent in the groundwater; or

(B) For any of the constituents listed in Table 1 to subpart A, the respective value given in that Table if the background level of the constituent is below the value given in the Table; or

(C) An alternate concentration limit established pursuant to paragraph (c)(3)(ii) of this section.

(ii)(A) The Secretary may apply an alternate concentration limit if, after considering remedial or corrective actions to achieve the levels specified in paragraphs (c)(3)(i)(A) and (B) of this section, he has determined that the constituent will not pose a substantial present or potential hazard to human health and the environment as long as the alternate concentration limit is not exceeded, and the Commission has concurred.

(B) In considering the present or potential hazard to human health and the environment of alternate concentration limits, the following factors shall be considered:

(*1*) Potential adverse effects on groundwater quality, considering:

(*i*) The physical and chemical characteristics of constituents in the residual radioactive material at the site, including their potential for migration;

(*ii*) The hydrogeological characteristics of the site and surrounding land;

(*iii*) The quantity of groundwater and the direction of groundwater flow;

(*iv*) The proximity and withdrawal rates of groundwater users;

(*v*) The current and future uses of groundwater in the region surrounding the site;

(*vi*) The existing quality of groundwater, including other sources of contamination and their cumulative impact on the groundwater quality;

(*vii*) The potential for health risks caused by human exposure to constituents;

(*viii*) The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents;

(*ix*) The persistence and permanence of the potential adverse effects;

(*x*) The presence of underground sources of drinking water and exempted aquifers identified under §144.7 of this chapter; and

(*2*) Potential adverse effects on hydraulically-connected surface-water quality, considering:

(*i*) The volume and physical and chemical characteristics of the residual radioactive material at the site;

(*ii*) The hydrogeological characteristics of the site and surrounding land;

(*iii*) The quantity and quality of groundwater, and the direction of groundwater flow;

(*iv*) The patterns of rainfall in the region;

(*v*) The proximity of the site to surface waters;

(*vi*) The current and future uses of surface waters in the region surrounding the site and any water quality standards established for those surface waters;

(*vii*) The existing quality of surface water, including other sources of contamination and their cumulative impact on surface water quality;

(*viii*) The potential for health risks caused by human exposure to constituents;

(*ix*) The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to constituents; and

(*x*) The persistence and permanence of the potential adverse effects.

(4) Point of compliance: The point of compliance is the location at which the groundwater concentration limits of paragraph (c)(3) of this section apply. The point of compliance is the intersection of a vertical plane with the uppermost aquifer underlying the site, located at the hydraulically downgradient limit of the disposal area plus the area taken up by any liner, dike, or other barrier designed to contain the residual radioactive material.

(d) Each site on which disposal occurs shall be designed and stabilized in a manner that minimizes the need for future maintenance.

[60 FR 2865, Jan. 11, 1995]

§ 192.03 Monitoring.

top

A groundwater monitoring plan shall be implemented, to be carried out over a period of time commencing upon completion of remedial actions taken to comply with the standards in §192.02, and of a duration which is adequate to demonstrate that future performance of the system of disposal can reasonably be expected to be in accordance with the design requirements of §192.02 (c). This plan and the length of the monitoring period shall be modified to incorporate any corrective actions required under §192.04 or §192.12(c).

[60 FR 2866, Jan. 11, 1995]

§ 192.04 Corrective action.

top

If the groundwater concentration limits established for disposal sites under provisions of §192.02(c) are found or projected to be exceeded, a corrective action program shall be placed into operation as soon as is practicable, and in no event later than eighteen (18) months after a finding of exceedance. This corrective action program will restore the performance of the system of disposal to the original concentration limits established under §192.02(c)(3), to the extent reasonably achievable, and, in any case, as a minimum shall:

(a) Conform with the groundwater provisions of §192.02(c)(3), and

(b) Clean up groundwater in conformance with subpart B, modified as appropriate to apply to the disposal site.

[60 FR 2866, Jan. 11, 1995]

Table 1 to Subpart A of Part 192—Maximum Concentration of Constituents for Groundwater Protection

top

Constituent concentration[1]	Maximum
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
Selenium	0.01
Silver	0.05
Nitrate (as N)	10.
Molybdenum	0.1
Combined radium-226 and radium-228	5 pCi/liter
Combined uranium-234 and uranium-238[2]	30 pCi/liter
Gross alpha-particle activity (excluding radon and uranium)	15 pCi/liter
Endrin (1,2,3,4,10,10-hexachloro-6,7-exposy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo,endo-5,8-dimethanonaphthalene)	0.0002
Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma insomer)	0.004
Methoxychlor (1,1,1-trichloro-2,2′-bis(p-methoxyphenylethane))	0.1
Toxaphene ($C_{10}H_{10}Cl_6$, technical chlorinated camphene, 67–69 percent chlorine)	0.005
2,4-D (2,4-dichlorophenoxyacetic acid)	0.1
2,4,5-TP Silvex (2,4,5-trichlorophenoxypropionic acid)	0.01

[1]Milligrams per liter, unless stated otherwise.

[2]Where secular equilibrium obtains, this criterion will be satisfied by a concentration of 0.044 milligrams per liter (0.044 mg/l). For conditions of other than secular equilibrium, a corresponding value may be derived and applied, based on the measured site-specific ratio of the two isotopes of uranium.

[60 FR 2866, Jan. 11, 1995]

Subpart B—Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites

top

§ 192.10 Applicability.

top

This subpart applies to land and buildings that are part of any processing site designated by the Secretary of Energy under section 102 of the Act. section 101 of the Act, states, in part, that “processing site” means—

(a) Any site, including the mill, containing residual radioactive materials at which all or substantially all of the uranium was produced for sale to any Federal agency prior to January 1, 1971, under a contract with any Federal agency, except in the case of a site at or near Slick Rock, Colorado, unless—

(1) Such site was owned or controlled as of Januray 1, 1978, or is thereafter owned or controlled, by any Federal agency, or

(2) A license (issued by the (Nuclear Regulatory) Commission or its predecessor agency under the Atomic Energy Act of 1954 or by a State as permitted under section 274 of such Act) for the production at site of any uranium or thorium product derived from ores is in effect on January 1, 1978, or is issued or renewed after such date; and

(b) Any other real property or improvement thereon which—

(1) Is in the vicinity of such site, and

(2) Is determined by the Secretary, in consultation with the Commission, to be contaminated with residual radioactive materials derived from such site.

§ 192.11 Definitions.

top

(a) Unless otherwise indicated in this subpart, all terms shall have the same meaning as defined in subpart A.

(b) *Land* means any surface or subsurface land that is not part of a disposal site and is not covered by an occupiable building.

(c) *Working Level* (WL) means any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of alpha particles with a total energy of 130 billion electron volts.

(d) *Soil* means all unconsolidated materials normally found on or near the surface of the earth including, but not limited to, silts, clays, sands, gravel, and small rocks.

(e) *Limited use groundwater* means groundwater that is not a current or potential source of drinking water because (1) the concentration of total dissolved solids is in excess of 10,000 mg/l, or (2) widespread, ambient contamination not due to activities involving residual radioactive materials from a designated processing site exists that cannot be cleaned up using treatment methods reasonably employed in public water systems, or (3) the quantity of water reasonably available for sustained continuous use is less than 150 gallons per day. The parameters for determining the quantity of water reasonably available shall be determined by the Secretary with the concurrence of the Commission.

[48 FR 602, Jan. 5, 1983, as amended at 60 FR 2866, Jan. 11, 1995]

§ 192.12 Standards.

top

Remedial actions shall be conducted so as to provide reasonable assurance that, *as a result of residual radioactive materials from any designated processing site:*

(a) The concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than—

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and

(2) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

(b) In any occupied or habitable building—

(1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL, and

(2) The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour.

(c) The Secretary shall comply with conditions specified in a plan for remedial action which provides that contamination of groundwater by listed constituents from residual radioactive material at any designated processing site (§192.01(1)) shall be brought into compliance as promptly as is reasonably achievable with the provisions of §192.02(c)(3) or any supplemental standards established under §192.22. For the purposes of this subpart:

(1) A monitoring program shall be carried out that is adequate to define backgroundwater quality and the areal extent and magnitude of groundwater contamination by listed constituents from residual radioactive materials (§192.02(c)(1)) and to monitor compliance with this subpart. The Secretary shall determine which of the constituents listed in Appendix I to part 192 are present in or could reasonably be derived from residual radioactive material at the site, and concentration limits shall be established in accordance with §192.02(c)(3).

(2) (i) If the Secretary determines that sole reliance on active remedial procedures is not appropriate and that cleanup of the groundwater can be more reasonably accomplished in full or in part through natural flushing, then the period for remedial procedures may be extended. Such an extended period may extend to a term not to exceed 100 years if:

(A) The concentration limits established under this subpart are projected to be satisfied at the end of this extended period,

(B) Institutional control, having a high degree of permanence and which will effectively protect public health and the environment and satisfy beneficial uses of groundwater during the extended period and which is enforceable by the administrative or judicial branches of government entities, is instituted and maintained, as part of the remedial action, at the processing site and wherever contamination by listed constituents from residual radioactive materials is found in groundwater, or is projected to be found, and

(C) The groundwater is not currently and is not now projected to become a source for a public water system subject to provisions of the Safe Drinking Water Act during the extended period.

(ii) Remedial actions on groundwater conducted under this subpart may occur before or after actions under Section 104(f)(2) of the Act are initiated.

(3) Compliance with this subpart shall be demonstrated through the monitoring program established under paragraph (c)(1) of this section at those locations not beneath a disposal site and its cover where groundwater contains listed constituents from residual radioactive material.

[48 FR 602, Jan. 5, 1983, as amended at 60 FR 2867, Jan. 11, 1995]

Subpart C—Implementation

top

§ 192.20 Guidance for implementation.

top

Section 108 of the Act requires the Secretary of Energy to select and perform remedial actions with the concurrence of the Nuclear Regulatory Commission and the full participation of any State that pays part of the cost, and in consultation, as appropriate, with affected Indian Tribes and the Secretary of the Interior. These parties, in their respective roles under section 108, are referred to hereafter as "the implementing agencies." The implementing agencies shall establish methods and procedures to provide "reasonable assurance" that the provisions of Subparts A and B are satisfied. This should be done as appropriate through use of analytic models and site-specific analyses, in the case of Subpart A, and for Subpart B through measurements performed within the accuracy of currently available types of field and laboratory instruments in conjunction with reasonable survey and sampling procedures. These methods and procedures may be varied to suit conditions at specific sites. In particular:

(a)(1) The purpose of Subpart A is to provide for long-term stabilization and isolation in order to inhibit misuse and spreading of residual radioactive materials, control releases of radon to air, and protect water. Subpart A may be implemented through analysis of the physical properties of the site and the control system and projection of the effects of natural processes over time. Events and processes that could significantly affect the average radon release rate from the entire disposal site should be considered. Phenomena that are localized or temporary, such as local cracking or burrowing of rodents, need to be taken into account only if their cumulative effect would be significant in determining compliance with the standard. Computational models, theories, and prevalent expert judgment may be used to decide that a control system design will satisfy the standard. The numerical range provided in the standard for the longevity of the effectiveness of the control of residual radioactive materials allows for consideration of the various factors affecting the longevity of control and stabilization methods and their costs. These factors have different levels of predictability and may vary for the different sites.

(2) Protection of water should be considered on a case-specific basis, drawing on hydrological and geochemical surveys and all other relevant data. The hydrologic and geologic assessment to be conducted at each site should include a monitoring program sufficient to establish background groundwater quality through one or more upgradient or other appropriately located wells. The groundwater monitoring list in Appendix IX of part 264 of this chapter (plus the additional constituents in Table A of this paragraph) may be used for screening purposes in place of Appendix I of part 192 in the monitoring program. New depository sites for tailings that contain water at greater than the level of "specific retention" should use aliner or equivalent. In considering design objectives for groundwater protection, the implementing agencies should give priority to concentration levels in the order listed under §192.02 (c)(3)(i). When considering the potential for health risks caused by human exposure to known or suspected carcinogens, alternate concentration limits pursuant to paragraph 192.02(c)(3)(ii) should be established at concentration levels which represent an excess

lifetime risk, at a point of exposure, to an average individual no greater than between $10^{-4}$and 10^{-6}.

Table A to §192.20(a)(2)—Additional Listed Constituents

Nitrate (as N)
Molybdenum
Combined radium-226 and radium-228
Combined uranium-234 and uranium-238
Gross alpha-particle activity (excluding radon and uranium)

(3) The plan for remedial action, concurred in by the Commission, will specify how applicable requirements of subpart A are to be satisfied. The plan should include the schedule and steps necessary to complete disposal operations at the site. It should include an estimate of the inventory of wastes to be disposed of in the pile and their listed constituents and address any need to eliminate free liquids; stabilization of the wastes to a bearing capacity sufficient to support the final cover; and the design and engineering specifications for a cover to manage the migration of liquids through the stabilized pile, function without maintenance, promote drainage and minimize erosion or abrasion of the cover, and accommodate settling and subsidence so that cover integrity is maintained. Evaluation of proposed designs to conform to subpart A should be based on realistic technical judgments and include use of available empirical information. The consideration of possible failure modes and related corrective actions should be limited to reasonable failure assumptions, with a demonstration that the disposal design is generally amenable to a range of corrective actions.

(4) The groundwater monitoring list in Appendix IX of part 264 of this chapter (plus the additional constituents in Table A in paragraph (a)(2) of this section) may be used for screening purposes in place of Appendix I of part 192 in monitoring programs. The monitoring plan required under §192.03 should be designed to include verification of site-specific assumptions used to project the performance of the disposal system. Prevention of contamination of groundwater may be assessed by indirect methods, such as measuring the migration of moisture in the various components of the cover, the tailings, and the area between the tailings and the nearest aquifer, as well as by direct monitoring of groundwater. In the case of vicinity properties (§192.01(l)(2)), such assessments may not be necessary, as determined by the Secretary, with the concurrence of the Commission, considering such factors as local geology and the amount of contamination present. Temporary excursions from applicable limits of groundwater concentrations that are attributable to a disposal operation itself shall not constitute a basis for considering corrective action under §1[illegible] during the disposal period, unless the disposal operation is suspended prior to completion for other than seasonal rea[illegible]

(b)(1) Compliance with §192.12(a) and (b) of subpart B, to the extent practical, should be demonstrated through radiation surveys. Such surveys may, if appropriate, be restricted to locations likely to contain residual radioactive materials. These surveys should be designed to provide for compliance averaged over limited areas rather than point-by-point compliance with the standards. In most cases, measurement of gamma radiation exposure rates above and below the land surface can be used to show compliance with §192.12(a). Protocols for making such measurements should be based on realistic radium distributions near the surface rather than extremes rarely encountered.

(2) In §192.12(a), "background level" refers to the native radium concentration in soil. Since this may not be determinable in the presence of contamination by residual radioactive materials, a surrogate "background level" may be established by simple direct or indirect (e.g., gamma radiation) measurements performed nearby but outside of the contaminated location.

(3) Compliance with §192.12(b) may be demonstrated by methods that the Department of Energy has approved for use under Pub. L. 92–314 (10 CFR part 712), or by other methods that the implementing agencies determine are adequate. Residual radioactive materials should be removed from buildings exceeding 0.03 WL so that future replacement buildings will not pose a hazard [unless removal is not practical—see §192.21(c)]. However, sealants, filtration, and ventilation devices may provide reasonable assurance of reductions from 0.03 WL to below 0.02 WL. In unusual cases, indoor radiation may exceed the levels specified in §192.12(b) due to sources other than residual radioactive materials. Remedial actions are not required in order to comply with the standard when there is reasonable assurance that residual radioactive materials are not the cause of such an excess.

(4) The plan(s) for remedial action will specify how applicable requirements of subpart B would be satisfied. The plan should include the schedule and steps necessary to complete the cleanup of groundwater at the site. It should document the extent of contamination due to releases prior to final disposal, including the identification and location of listed constituents and the rate and direction of movement of contaminated groundwater, based upon the monitoring carried out under §192.12(c)(1). In addition, the assessment should consider future plume movement, including an evaluation of such processes as attenuation and dilution and future contamination from beneath a disposal site. Monitoring for assessment and compliance purposes should be sufficient to establish the extent and magnitude of contamination, with reasonable assurance, through use of a carefully chosen minimal number of sampling locations. The location and number of monitoring wells, the frequency and duration of monitoring, and the selection of indicator analytes for long-term groundwater monitoring, and, more generally, the design and operation of the monitoring system, will depend on the potential for risk to receptors and upon other factors, including characteristics of the subsurface environment, such as velocity of groundwater flow, contaminant retardation, time of groundwater or contaminant transit to receptors, results of statistical evaluations of data trends, and modeling of the dynamics of the groundwater system. All of these fa[illegible]hould be incorporated into the design of a site-specific monitoring program that will achieve the purpose of the regulations in [illegible]bpart in the most cost-effective manner. In the case of vicinity properties (§192.01(l)(2)), such assessments will usually not be necessary. The Secretary, with the concurrence of the Commission, may consider such factors as local geology and amount of contamination present in determining criteria to decide when such assessments are needed. In cases where §192.12(c)(2) is invoked, the plan should include a monitoring program sufficient to verify projections of plume movement and attenuation periodically during the extended cleanup period. Finally, the plan should specify details of the method to be used for cleanup of

groundwater.

[48 FR 602, Jan. 5, 1983, as amended at 60 FR 2867, Jan. 11, 1995]

§ 192.21 Criteria for applying supplemental standards.

top

Unless otherwise indicated in this subpart, all terms shall have the same meaning as defined in Title I of the Act or in subparts A and B. The implementing agencies may (and in the case of paragraph (h) of this section shall) apply standards under §192.22 in lieu of the standards of subparts A or B if they determine that any of the following circumstances exists:

(a) Remedial actions required to satisfy subpart A or B would pose a clear and present risk of injury to workers or to members of the public, notwithstanding reasonable measures to avoid or reduce risk.

(b) Remedial actions to satisfy the cleanup standards for land, §192.12(a), and groundwater, §192.12(c), or the acquisition of minimum materials required for control to satisfy §§192.02(b) and (c), would, notwithstanding reasonable measures to limit damage, directly produce health and environmental harm that is clearly excessive compared to the health and environmental benefits, now or in the future. A clear excess of health and environmental harm is harm that is long-term, manifest, and grossly disproportionate to health and environmental benefits that may reasonably be anticipated.

(c) The estimated cost of remedial action to satisfy §192.12(a) at a "vicinity" site (described under section 101(6)(B) of the Act) is unreasonably high relative to the long-term benefits, and the residual radioactive materials do not pose a clear present or future hazard. The likelihood that buildings will be erected or that people will spend long periods of time at such a vicinity site should be considered in evaluating this hazard. Remedial action will generally not be necessary where residual radioactive materials have been placed semi-permanently in a location where site-specific factors limit their hazard and from which they are costly or difficult to remove, or where only minor quantities of residual radioactive materials are involved. Examples are residual radioactive materials under hard surface public roads and sidewalks, around public sewer lines, or in fence post foundations. Supplemental standards should not be applied at such sites, however, if individuals are likely to be exposed for long periods of time to radiation from such materials at levels above those that would prevail under §192.12(a).

(d) The cost of a remedial action for cleanup of a building under §192.12(b) is clearly unreasonably high relative to the benefits. Factors that should be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be affected by the remedial action, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of less costly remedial methods than removal of residual radioactive materials.

(e) There is no known remedial action.

(f) The restoration of groundwater quality at any designated processing site under §192.12(c) is technically impracticable from an engineering perspective.

(g) The groundwater meets the criteria of §192.11(e).

(h) Radionuclides other than radium-226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials.

[48 FR 602, Jan. 5, 1983, as amended at 60 FR 2868, Jan. 11, 1995]

§ 192.22 Supplemental standards.

top

Federal agencies implementing subparts A and B may in lieu thereof proceed pursuant to this section with respect to generic or individual situations meeting the eligibility requirements of §192.21.

(a) When one or more of the criteria of §192.21(a) through (g) applies, the Secretary shall select and perform that alternative remedial action that comes as close to meeting the otherwise applicable standard under §192.02(c)(3) as is reasonably achievable.

(b) When §192.21(h) applies, remedial actions shall reduce other residual radioactivity to levels that are as low as is reasonably achievable and conform to the standards of subparts A and B to the maximum extent practicable.

(c) The implementing agencies may make general determinations concerning remedial actions under this section that will apply to all locations with specified characteristics, or they may make a determination for a specific location. When remedial actions are proposed under this section for a specific location, the Department of Energy shall inform any private owners and occupants of the affected location and solicit their comments. The Department of Energy shall provide any such comments to the other implementing agencies. The Department of Energy shall also periodically inform the Environmental Protection Agency of both *general and individual determinations under the provisions of this section.*

(d) When §192.21(b), (f), or (g) apply, implementing agencies shall apply any remedial actions for the restoration of contamination of groundwater by residual radioactive materials that is required to assure, at a minimum, protection of human health and the environment. In addition, when §192.21(g) applies, supplemental standards shall ensure that current and reasonably projected uses of the affected groundwater are preserved.

[48 FR 602, Jan. 5, 1983, as amended at 60 FR 2868, Jan. 11, 1995]

§ 192.23 Effective date.

top

Subparts A, B, and C shall be effective March 7, 1983.

Subpart D—Standards for Management of Uranium Byproduct Materials Pursuant to Section 84 of the Atomic Energy Act of 1954, as Amended

top

Source: 48 FR 45946, Oct. 7, 1983, unless otherwise noted.

§ 192.30 Applicability.

top

This subpart applies to the management of uranium byproduct materials under section 84 of the Atomic Energy Act of 1954 (henceforth designated "the Act"), as amended, during and following processing of uranium ores, and to restoration of disposal sites following any use of such sites under section 83(b)(1)(B) of the Act.

§ 192.31 Definitions and cross-references.

top

References in this subpart to other parts of the Code of Federal Regulations are to those parts as codified on January 1, 1983.

(a) Unless otherwise indicated in this subpart, all terms shall have the same meaning as in Title II of the Uranium Mill Tailings Rediation Control Act of 1978, subparts A and B of this part, or parts 190, 260, 261, and 264 of this chapter. For the purposes of this subpart, the terms "waste," "hazardous waste," and related terms, as used in parts 260, 261, and 264 of this chapter shall apply to byproduct material.

(b) *Uranium byproduct material* means the tailings or wastes produced by the extraction or concentration of uranium from any ore processed primarily for its source material content. Ore bodies depleted by uranium solution extraction operations and which remain underground do not constitute "byproduct material" for the purpose of this subpart.

(c) *Control* means any action to stabilize, inhibit future misuse of, or reduce emissions or effluents from uranium byproduct materials.

(d) *Licensed site* means the area contained within the boundary of a location under the control of persons generating or storing uranium byproduct materials under a license issued pursuant to section 84 of the Act. For purposes of this subpart, "licensed site" is equivalent to "regulated unit" in subpart F of part 264 of this chapter.

(e) *Disposal site* means a site selected pursuant to section 83 of the Act.

(f) *Disposal area* means the region within the perimeter of an impoundment or pile containing uranium by product materials to which the post-closure requirements of §192.32(b)(1) of this subpart apply.

(g) *Regulatory agency* means the U.S. Nuclear Regulatory Commission.

(h) *Closure period* means the period of time beginning with the cessation, with respect to a waste impoundment, of uranium ore processing operations and ending with completion of requirements specified under a closure plan.

(i) *Closure plan* means the plan required under §264.112 of this chapter.

(j) *Existing portion* means that land surface area of an existing surface impoundment on which significant quantities of uranium byproduct materials have been placed prior to promulgation of this standard.

(k) *As expeditiously as practicable considering technological feasibility* means as quickly as possible considering: the physical characteristics of the tailings and the site; the limits of available technology; the need for consistency with mandatory requirements of other regulatory programs; and factors beyond the control of the licensee. The phrase permits consideration of the cost of compliance only to the extent specifically provided for by use of the term "available technology."

(l) *Permanent Radon Barrier* means the final radon barrier constructed to achieve compliance with, including attainment of, the limit on releases of radon-222 in §192.32(b)(1)(ii).

(m) *Available technology* means technologies and methods for emplacing a permanent radon barrier on uranium mill tailings piles or impoundments. This term shall not be construed to include extraordinary measures or techniques that would impose costs that are grossly excessive as measured by practice within the industry or one that is reasonably analogous, (such as, by way of illustration only, unreasonable overtime, staffing or transportation requirements, etc., considering normal practice in the industry; laser fusion, of soils, etc.), provided there is reasonable progress toward emplacement of a permanent radon barrier. To determine grossly excessive costs, the relevant baseline against which cost increases shall be compared is the cost estimate for tailings impoundment closure contained in the licensee's tailings closure plan, but costs beyond such estimates shall not automatically be considered grossly excessive.

(n) *Tailings Closure Plan (Radon)* means the Nuclear Regulatory Commission or Agreement State approved plan detailing activities to accomplish timely emplacement of a permanent radon barrier. A tailings closure plan shall include a schedule for key radon closure milestone activities such as wind blown tailings retrieval and placement on the pile, interim stabilization (including dewatering or the removal of freestanding liquids and recontouring), and emplacement of a permanent radon barrier constructed to achieve compliance with the 20 pCi/m^2 -s flux standard as expeditiously as practicable considering technological feasibility (including factors beyond the control of the licensee).

(o) *Factors beyond the control of the licensee* means factors proximately causing delay in meeting the schedule in the applicable license for timely emplacement of the permanent radon barrier notwithstanding the good faith efforts of the licensee to achieve compliance. These factors may include, but are not limited to, physical conditions at the site; inclement weather or climatic conditions; an act of God; an act of war; a judicial or administrative order or decision, or change to the statutory, regulatory, or other legal requirements applicable to the licensee's facility that would preclude or delay the performance of activities required for compliance; labor disturbances; any modifications, cessation or delay ordered by state, Federal or local agencies; delays beyond the time reasonably required in obtaining necessary governmental permits, licenses, approvals or consent for activities described in the tailings closure plan (radon) proposed by the licensee that result from agency failure to take final action after the licensee has made a good faith, timely effort to submit legally sufficient applications, responses to requests (including relevant data requested by the agencies), or other information, including approval of the tailings closure plan by NRC or the affected Agreement State; and an act or omission of any third party over whom the licensee has no control.

(p) *Operational* means that a uranium mill tailings pile or impoundment is being used for the continued placement of uranium byproduct material or is in standby status for such placement. A tailings pile or impoundment is operational from the day that uranium byproduct material is first placed in the pile or impoundment until the day final closure begins.

(q) *Milestone* means an enforceable date by which action, or the occurrence of an event, is required for purposes of achieving compliance with the 20 pCi/m^2 –s flux standard.

[48 FR 45946, Oct. 7, 1983, as amended at 58 FR 60355, Nov. 15, 1993]

§ 192.32 Standards.

top

(a) *Standards for application during processing operations and prior to the end of the closure period.* (1) Surface impoundments (except for an existing portion) subject to this subpart must be designed, constructed, and installed in such manner as to conform to the requirements of §264.221 of this chapter, except that at sites where the annual precipitation falling on the impoundment and any drainage area contributing surface runoff to the impoundment is less than the annual evaporation from the impoundment, the requirements of §264.228(a)(2) (iii)(E) referenced in §264.221 do not apply.

(2) Uranium byproduct materials shall be managed so as to conform to the ground water protection standard in §264.92 of this chapter, except that for the purposes of this subpart:

(i) To the list of hazardous constituents referenced in §264.93 of this chapter are added the chemical elements molybdenum and uranium,

(ii) To the concentration limits provided in Table 1 of §264.94 of this chapter are added the radioactivity limits in Table A of this subpart.

(iii) Detection monitoring programs required under §264.98 to establish the standards required under §264.92 shall be completed within one (1) year of promulgation,

(iv) The regulatory agency may establish alternate concentration limits (to be satisfied at the point of compliance specified under §264.95) under the criteria of §264.94(b), provided that, after considering practicable corrective actions, these limits are as low as reasonably achievable, and that, in any case, the standards of §264.94(a) are satisfied at all points at a greater distance than 500 meters from the edge of the disposal area and/or outside the site boundary, and

(v) The functions and responsibilities designated in Part 264 of this chapter as those of the "Regional Administrator" with respect to "facility permits" shall be carried out by the regulatory agency, except that exemptions of hazardous constituents under §264.93 (b) and (c) of this chapter and alternate concentration limits established under §264.94 (b) and (c) of this chapter (except as otherwise provided in §192.32(a)(2)(iv)) shall not be effective until EPA has concurred therein.

(3)(i) Uranium mill tailings piles or impoundments that are nonoperational and subject to a license by the Nuclear Regulatory Commission or an Agreement State shall limit releases of radon-222 by emplacing a permanent radon barrier. This permanent radon barrier shall be constructed as expeditiously as practicable considering technological feasibility (including factors beyond the control of the licensee) after the pile or impoundment ceases to be operational. Such control shall be carried out in accordance with a written tailings closure plan (radon) to be incorporated by the Nuclear Regulatory Commission or Agreement State into individual site licenses.

(ii) The Nuclear Regulatory Commission or Agreement State may approve a licensee's request to extend the time for performance of milestones if, after providing an opportunity for public participation, the Nuclear Regulatory Commission or Agreement State finds that compliance with the 20 pCi/m^2 –s flux standard has been demonstrated using a method approved by the NRC, in the manner required in 192.32(a)(4)(i). Only under these circumstances and during the period of the extension must compliance with the 20 pCi/m^2 –s flux standard be demonstrated each year.

(iii) The Nuclear Regulatory Commission or Agreement State may extend the final compliance date for emplacement of the permanent radon barrier, or relevant milestone, based upon cost if the new date is established after a finding by the Nuclear Regulatory Commission or Agreement State, after providing an opportunity for public participation, that the licensee is making good faith efforts to emplace a permanent radon barrier; the delay is consistent with the definition of "available technology" in §192.31(m); and the delay will not result in radon releases that are determined to result in significant incremental risk to the public health.

(iv) The Nuclear Regulatory Commission or Agreement State may, in response to a request from a licensee, authorize by license or license amendment a portion of the site to remain accessible during the closure process to accept uranium byproduct material as defined in section 11(e)(2) of the Atomic Energy Act, 42 U.S.C. 2014(e)(2), or to accept materials similar to the physical, chemical and radiological characteristics of the in situ uranium mill tailings and associated wastes, from other sources. No such authorization may be used as a means for delaying or otherwise impeding emplacement of the permanent radon barrier over the remainder of the pile or impoundment in a manner that will achieve compliance with the 20 pCi/m^2 –s flux standard, averaged over the entire pile or impoundment.

(v) The Nuclear Regulatory Commission or Agreement State may, in response to a request from a licensee, authorize by license or license amendment a portion of a pile or impoundment to remain accessible after emplacement of a permanent radon barrier to accept uranium byproduct material as defined in section 11(e)(2) of the Atomic Energy Act, 42 U.S.C. 2014(e)(2), if compliance with the 20 pCi/m^2 –s flux standard of §192.32(b)(1)(ii) is demonstrated by the licensee's monitoring conducted in a manner consistent with §192.32(a)(4)(i). Such authorization may be provided only if the Nuclear Regulatory Commission or Agreement State makes a finding, constituting final agency action and after providing an opportunity for public participation, that the site will continue to achieve the 20 pCi/m2–s flux standard when averaged over the entire impoundment.

(4)(i) Upon emplacement of the permanent radon barrier pursuant to 40 CFR 192.32(a)(3), the licensee shall conduct appropriate monitoring and analysis of the radon-222 releases to demonstrate that the design of the permanent radon barrier is effective in limiting releases of radon-222 to a level not exceeding 20 pCi/m^2 –s as required by 40 CFR 192.32(b)(1)(ii). This monitoring shall be conducted using the procedures described in 40 CFR part 61, Appendix B, Method 115, or any other measurement method proposed by a licensee that the Nuclear Regulatory Commission or Agreement State approves as being at least as effective as EPA Method 115 in demonstrating the effectiveness of the permanent radon barrier in achieving compliance with the 20 pCi/m^2 –s flux standard.

(ii) When phased emplacement of the permanent radon barrier is included in the applicable tailings closure plan (radon), then radon flux monitoring required under §192.32(a)(4)(i) shall be conducted, however the licensee shall be allowed to conduct such monitoring for each portion of the pile or impoundment on which the radon barrier has been emplaced by conducting flux monitoring on the closed portion.

(5) Uranium byproduct materials shall be managed so as to conform to the provisions of:

(i) Part 190 of this chapter, "Environmental Radiation Protection Standards for Nuclear Power Operations" and

(ii) Part 440 of this chapter, "Ore Mining and Dressing Point Source Category: Effluent Limitations Guidelines and New Source Performance Standards, Subpart C, Uranium, Radium, and Vanadium Ores Subcategory."

(6) The regulatory agency, in conformity with Federal Radiation Protection Guidance (FR, May 18, 1960, pgs. 4402–4403), shall make every effort to maintain radiation doses from radon emissions from surface impoundments of uranium byproduct materials as far below the Federal Radiation Protection Guides as is practicable at each licensed site.

(b) *Standards for application after the closure period.* At the end of the closure period:

(1) Disposal areas shall each comply with the closure performance standard in §264.111 of this chapter with respect to nonradiological hazards and shall be designed[1] to provide reasonable assurance of control of radiological hazards to

[1] The standard applies to design with a monitoring requirement as specified in §192.32(a)(4).

(i) Be effective for one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years, and,

(ii) Limit releases of radon-222 from uranium byproduct materials to the atmosphere so as to not exceed an average[2] release rate of 20 picocuries per square meter per second (pCi/m2s).

[2] This average shall apply to the entire surface of each disposal area over periods of at least one year, but short compared to 100 years. Radon will come from both uranium byproduct materials and from covering materials. Radon emissions from covering materials should be estimated as part of developing a closure plan for each site. The standard, however, applies only to emissions from uranium byproduct materials to the atmosphere.

(2) The requirements of §192.32(b)(1) shall not apply to any portion of a licensed and/or disposal site which contains a concentration of radium-226 in land, averaged over areas of 100 square meters, which, as a result of uranium byproduct material, does not exceed the background level by more than:

(i) 5 picocuries per gram (pCi/g), averaged over the first 15 centimeters (cm) below the surface, and

(ii) 15 pCi/g, averaged over 15 cm thick layers more than 15 cm below the surface.

[48 FR 45946, Oct. 7, 1983, as amended at 58 FR 60355–60356, Nov. 15, 1993]

§ 192.33 Corrective action programs.

top

If the ground water standards established under provisions of §192.32(a)(2) are exceeded at any licensed site, a corrective action program as specified in §264.100 of this chapter shall be put into operation as soon as is practicable, and in no event later than eighteen (18) months after a finding of exceedance.

§ 192.34 Effective date.

top

Subpart D shall be effective December 6, 1983.

Table A to Subpart D of Part 192

top

	pCi/liter
Combined radium-226 and radium-228	5
Gross alpha-particle activity (excluding radon and uranium)	15

Subpart E—Standards for Management of Thorium Byproduct Materials Pursuant to Section 84 of the Atomic Energy Act of 1954, as Amended

top

Source: 48 FR 45947, Oct. 7, 1983, unless otherwise noted.

§ 192.40 Applicability.

top

This subpart applies to the management of thorium byproduct materials under section 84 of the Atomic Energy Act of 1954, as amended, during and following processing of thorium ores, and to restoration of disposal sites following any use of such sites under section 83(b)(1)(B) of the Act.

§ 192.41 Provisions.

top

Except as otherwise noted in §192.41(e), the provisions of subpart D of this part, including §§192.31, 192.32, and 192.33, shall apply to thorium byproduct material and:

(a) Provisions applicable to the element uranium shall also apply to the element thorium;

(b) Provisions applicable to radon-222 shall also apply to radon-220; and

(c) Provisions applicable to radium-226 shall also apply to radium-228.

(d) Operations covered under §192.32(a) shall be conducted in such a manner as to provide reasonable assurance that the annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as a result of exposures to the planned discharge of radioactive materials, radon-220 and its daughters excepted, to the general environment.

(e) The provisions of §192.32(a) (3) and (4) do not apply to the management of thorium byproduct material.

[48 FR 45946, Oct. 7, 1983, as amended at 58 FR 60356, Nov. 15, 1993]

§ 192.42 Substitute provisions.

top

The regulatory agency may, with the concurrence of EPA, substitute for any provisions of §192.41 of this subpart alternative provisions it deems more practical that will provide at least an equivalent level of protection for human health and the environment.

§ 192.43 Effective date.

top

Subpart E shall be effective December 6, 1983.

Appendix I to Part 192—Listed Constituents

top

Acetonitrile

Acetophenone (Ethanone, 1-phenyl)

2-Acetylaminofluorene (Acetamide, N-9H-fluoren-2-yl-)

Acetyl chloride

1-Acetyl-2-thiourea (Acetamide, N-(aminothioxymethyl)-)

Acrolein (2-Propenal)

Acrylamide (2-Propenamide)

Acrylonitrile (2-Propenenitrile)

Aflatoxins

Aldicarb (Propenal, 2-methyl-2-(methylthio)-,O-[(methylamino)carbonyl]oxime

Aldrin (1,4:5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro(1α,4α,4aβ,5α,8α,8αβ)-)

Allyl alcohol (2-Propen-1-ol)

Allyl chloride (1-Propane,3-chloro)

Aluminum phosphide

4-Aminobiphenyl ([1,1′-Biphenyl]-4-amine)

5-(Aminomethyl)-3-isoxazolol (3(2H)-Isoxazolone,5-(aminomethyl)-)

4-Aminopyridine (4-Pyridineamine)

Amitrole (IH-1,2,4-Triazol-3-amine)

Ammonium vanadate (Vanadic acid, ammonium salt)

Aniline (Benzenamine)

Antimony and compounds, N.O.S.[1]

[1] The abbreviation N.O.S. (not otherwise specified) signifies those members of the general class not specifically listed by name in this appendix.

Aramite (Sulfurous acid, 2-chloroethyl 2-[4-(1,1-dimethylethyl)phenoxy]-1-methylethyl ester)

Arsenic and compounds, N.O.S.

Arsenic acid (Arsenic acid H_3AsO_4)

Arsenic pentoxide (Arsenic oxide As_2O_5)

Auramine (Benzamine, 4,4′-carbonimidoylbis[N,N-dimethyl-])

Azaserine (L-Serine, diazoacetate (ester))

Barium and compounds, N.O.S.

Barium cyanide

Benz[c]acridine (3,4-Benzacridine)

Benz[a]anthracene (1,2-Benzanthracene)

SUPPLEMENTAL TECHNICAL EVALUATION REPORT
TITLE I GROUND-WATER REMEDIATION

DATE: July 13, 1998

FACILITY: Ambrosia Lake, New Mexico, Title I Site

PROJECT MANAGER: Kenneth Hooks

TECHNICAL REVIEWER: William Ford

BACKGROUND:

The U.S. Department of Energy (DOE) submitted a Final Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill tailings at Ambrosia Lake, New Mexico, by letter dated September 30, 1990. The NRC staff reviewed the remedial action plan and conditionally concurred on the proposed remedial action in its Technical Evaluation Report (TER) transmitted on December 31, 1990.

In the TER, the NRC staff concurred with the application of supplemental standards at the Ambrosia Lake disposal site under 40 CFR 192, Subpart C. The staff concluded that, "DOE has adequately justified that the proposed supplemental standards are protective of human health and the environment." The classification of the ground water as Class III (i.e., the ground water that is not a current or potential source of drinking water) leads to a ground-water compliance strategy of no remediation. Furthermore, in the TER the NRC staff concurred with the DOE that this site should be exempted from both compliance and performance ground-water monitoring requirements.

This Supplemental Technical Evaluation Report documents the NRC staff review of DOE's Ground Water Compliance Action Plan for the Ambrosia Lake, New Mexico, site, which was transmitted by letter dated June 1, 1998, and confirms the staff concurrence documented in its December, 1990, Technical Evaluation Report.

SUMMARY AND CONCLUSIONS:

Staff has determined that the DOE's Ground Water Compliance Action Plan satisfies the requirements set forth in the Uranium Mill Tailings Radiation Control Act of 1978, as amended (UMTRCA), and the standards in 40 CFR 192, Subparts B and C, for the cleanup of ground-water contamination resulting from the processing of ores for the extraction of uranium. No modifications to the DOE's Long Term Surveillance Plan are required by this action.

Enclosure

DESCRIPTION OF DOE'S REQUEST:

DOE submitted information in support of its earlier decision that ground-water restoration and long-term monitoring activities were not required at the Ambrosia Lake site.

TECHNICAL EVALUATION:

The NRC staff concurs with the DOE conclusions that the uppermost aquifer at the Ambrosia Lake site does not represent a ground-water resource because of the limited extent of saturation and the inability to consistently sustain a yield of 150 gallons (570 liters per day to wells. In addition, the uppermost aquifer is expected to return to its premilling and mining condition of little-to-no saturation, further eliminating the unit as a potential future ground-water resource. This is because the major sources of recharge, water disposal and infiltration, and water from mine pumping, no longer exist. Ground water does not discharge to the land surface and the nearest surface water is located approximately 1.5 mi (2.4 Km) southwest of the site. Land use in the future is not expected to change. Therefore, no current exposure pathways due to ground-water contamination to humans, livestock, or wildlife exist, nor are any foreseen. The DOE has further determined that a program to monitor ground water is not required for the Ambrosia Lake site because ground water in the uppermost aquifer is of limited use.

The NRC staff concurs with the decision that ground-water restoration should not be conducted and that long-term ground-water monitoring is not required at this site. The staff also concludes that the approach described in the Ground Water Compliance Action Plan is consistent with requirements in the regulations and DOE's Programmatic Environmental Impact Statement. Therefore, the NRC staff concurs with the DOE ground water reclamation plan for the Ambrosia Lake site.

REFERENCES:

U.S. Department of Energy, 1990. Remedial Action Plan and Site Conceptual Design for the Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico, Final. UMTRA-DOA/AL-650516.0000, September 1990. Transmitted by DOE letter dated September 25, 1990.

U.S. Department of Energy, 1991, Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico, Final Appendix B, UMTRA-DOE/AL-050516.0000, November 1991.

U.S. Department of Energy, 1995a, Site Observational Work Plan for the UMTRA Project Site at Ambrosia Lake, New Mexico, DOE/AL/62350-159, Rev. 0, February 1995.

U.S. Department of Energy, 1995b. Supplement to the Site Observational Work Plan for the UMTRA Project Site at Ambrosia Lake, New Mexico, DOE/AL/62350-159S, Rev. 0, November 1995.

U.S. Department of Energy, 1996. Long-Term Surveillance Plan for the Ambrosia Lake, New Mexico Disposal Site, DE/AL/62350-211, Rev 1, July.

U.S. Department of Energy, 1996. Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project, DOE/EIS-0198, October 1996.

U.S. Department of Energy, 1998a. UMTRA Ground Water Project Ground Water Document Compilation, Ambrosia Lake, New Mexico, April 1998. Transmitted by DOE letter dated June 1, 1998.

U.S. Department of Energy, 1998b. Ground Water Compliance Action Plan (GCAP) for the UMTRA Project Site at Ambrosai Lake, New Mexico, May 1998. Transmitted by DOE letter dated June 1, 1998.

U.S. Nuclear Regulatory Commission, 1990. Final Technical Evaluation Report for DOE's Proposed Remedial Action, Ambrosia Lake UMTRA Project Site, New Mexico, December 1990. Transmitted by NRC letter dated December 31, 1990.

U.S. Nuclear Regulatory Commission, 1996. Site Observational Work Plan for the Ambrosia Lake Uranium Mill Tailings Remedial Action Project Site, April 9, 1996.

U.S. Nuclear Regulatory Commission, 1997. Ambrosia Lake Completion Report, May 1,1997.

(GCAP)

May 21, 1998

40 CFR 192 (Subpart B) Ground Water Compliance Modification to the Remedial Action Plan and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico (November, 1991)

The following sections will be modified:

SECTION 2.0 EPA STANDARDS
Subsection 2.4 Water-Quality Protection;

SECTION 5.0 GROUNDWATER PROTECTION

To achieve compliance with Subpart B of 40 CFR 192, (aquifer restoration) at the Ambrosia Lake, New Mexico, UMTRA site, the DOE proposes implementation of the No-Ground-Water-Remediation strategy. This determination utilizes a consistent and objective strategy selection framework developed in the Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project (October, 1996).

In summary, the No-Ground-Water-Remediation strategy is based on ground water in the uppermost aquifer being classified as limited use, thus providing the basis for the application of supplemental standards. The term "limited use" is defined in the final EPA ground water standards (60 FR 2854). The uppermost aquifer does not represent a ground water resource because of the limited extent of saturation and the inability to sustain a yield of 150 gallons per day to wells. The sources of past recharge such as waste water disposal and infiltration, and water from mine pumping, no longer exist. Further, the tailings and other contaminated material are now encapsulated in a long-term engineered disposal cell. The disposal cell has a cover design feature that will minimize infiltration through the tailings. Therefore, the saturated unit (uppermost aquifer) is expected to return to its premilling and mining condition of little-to-no saturation, further eliminating the unit as a potential future ground water resource.

The DOE has determined that the ground water in the uppermost aquifer was contaminated by uranium processing activities at the Ambrosia Lake site, but qualifies for supplemental standards based on the limited-use conditions. This decision was determined by applying the decision-framework developed in the Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project (October, 1996) as the strategy selection process in the Site Observational Work Plan (SOWP) for the UMTRA Project Site, at Ambrosia Lake, New Mexico (February, 1995, and subsequent addendum's). The framework as applied to the Ambrosia Lake site consists of five evaluative steps that are discussed below.

The first step of the decision framework was an assessment of existing data. The uppermost aquifer is defined as the alluvium and Tres Hermanos-C Sandstone. Ground water contaminants are a result of uranium processing activities that occurred from 1958 until 1963. Section 3.0 of the SOWP provides a conceptual site model that includes the hydrogeologic setting, nature and extent of ground water contamination, contaminant fate and transport, and risk evaluation. Evaluation of previous site data, and additional field data collection - at the request of the State of New Mexico (1997), coupled with the Ambrosia Lake site conceptual model indicate that sufficient hydrological and ground water contamination characterization data exists to make an appropriate (Subpart B) compliance strategy selection.

The second step compares the list of ground water contaminants with MCLs or background ground water quality. However, this site is unique because background ground water quality in the alluvium and the

Tres Hermanos-C standstone at the Ambrosia lake site is considered to be the same as existing water quality due to the limited-saturation created by the past mining and milling activities. Outside of the limited saturation, the unit is essentially dry. Within the area of limited-saturation contaminants that have exceeded MCLs in the past includes uranium, selenium, cadmium, chromium, molybdenum, nitrate, combined radium -226 and -288, and arsenic. An additional constituent that is an indicator of process-related contaminated ground water is sulfate. Ground water contaminants from the uranium milling operation have seeped into the subsurface and migrated into the ground water system creating a limited zone of saturation that encompasses an area slightly larger than the fenced disposal site.

The third step determines whether the contaminated ground water qualifies for supplemental standards based on the classification of ground water as limited use. The conceptual model reasonably depicts the uppermost aquifer's hydraulic properties as unable to sustain a yield of 150 gallons per day to wells. Additional field work conducted in 1997 adds further confidence that the limited-saturation is well defined and the Tres Hermanos-B is contaminated in one very localized area, and the Dakota is not contaminated. With time the limited saturated zone created by past mining and milling practices will diminish.

The fourth step determines whether human health and environmental risks that result from applying supplemental standards are acceptable. There is no risk to human health and the environment because there are no known exposure pathways, for ground water from the uppermost aquifer to reach a receptor. No one is using or is projected to use the ground water from this aquifer for any purpose. Further, there is no discharge of ground water from the uppermost aquifer to a deeper aquifer used for domestic and/or agricultural purposes, nor a surface water body or surface expression.

The fifth and final step in the framework selects an appropriate compliance strategy to meet the EPA ground water standards. The selected strategy is to perform no remediation based on ground water in the uppermost aquifer being classified as limited use, which allows the application of supplemental standards. Limited use ground water at the Ambrosia Lake site is neither a current nor potential source of drinking water because of low yield and its transient nature (diminishing with time) that cannot be cleaned up using treatment methods reasonably employed in public water supply systems (40 CFR 192.11(e)).

Details supporting the 1) regulatory framework requirements, 2) summary of site conditions, and 3) ground water compliance strategy selection can be found in the Ground Water Document Compilation, Ambrosia Lake, New Mexico (April, 1998). This compilation includes all NEPA documentation, the SOWP, and supplements, and pertinent correspondence with the Nuclear Regulatory Commission and the State of New Mexico.

U.S. Department of Energy
Grand Junction Office
2597 B¾ Road
Grand Junction, CO 81503

JUN 01 1998

Marcy Leavitt, Bureau Chief
Ground Water Protection and Remediation Bureau
Harold Runnels Building
1190 St. Francis Drive
Santa Fe, NM 87502

Subject: Transmittal of Ground Water Compliance Action Plan and Supporting Background Information for the Ambrosia Lake, New Mexico, Title I UMTRA Site (Subpart B Compliance)

Dear Ms. Leavitt:

Enclosed are two copies of the *Ground Water Compliance Action Plan (GCAP)) for the UMTRA Project Site at Ambrosia Lake, New Mexico, May 1998*. Accompanying the GCAP are two 3-ring binders of supporting background information that includes the Site Observation Work Plan, analyses of the most recent field characterization data, and other pertinent documentation.

The GCAP is submitted as the 40 CFR 192, Subpart B, ground water modification to the Remedial Action Plan (RAP) and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico (November 1991). The GCAP will serve as replacement of the current text identified in the RAP: Sections 2.0 EPA Standards, Subsection 2.4 Water-Quality Protection, and Section 5.0 Groundwater Protection.

Concurrent with this transmittal, the Department of Energy (DOE) UMTRA Ground Water Project is transmitting copies of the GCAP and supporting background information to the Nuclear Regulatory Commission (NRC) for concurrence.

The final *Programmatic Environmental Impact Statement* (PEIS) for the UMTRA Ground Water Project was approved for distribution on September 19, 1996. Distribution of the final PEIS began in October of 1996. The Record of Decision was approved and published in April 1997. In 1998, the DOE Ground Water Project has completed the necessary site-specific National Environmental Policy Act documentation for Subpart B compliance at the Ambrosia Lake Site.

The Ambrosia Lake tailings were stabilized in place, encapsulated within an engineered disposal cell that was constructed to Title I design specifications. The residual radioactive material is managed under the Title I general license. The second part of the two-step general license process (10 CFR 40.27) for the Ambrosia Lake Site will be completed with NRC's concurrence on the GCAP. Further performance assessment monitoring is not required with the selection of the No-Ground-Water Remediation Strategy. The Long-Term Surveillance and Maintenance Project will continue with annual inspections under their long-term care requirements.

Please provide your review comments or approval as soon as possible. If you have questions or need further clarification, call me at (970) 248-7612.

Sincerely,

Donald R. Metzler, P.Hg.
Technical/Project Manager

Enclosures:
GCAP
3-ring binder of supporting documentation

cc w/o enclosure:
J. Holonich, NRC
M. Layton, NRC
S. McKitrick, NMED
File GWAMB1.4 (P. Taylor)

drm\nmamb.doc

UAMB000066

U.S. Department of Energy
Grand Junction Office
2597 B¾ Road
Grand Junction, CO 81503

JUN 01 1998

Joseph J. Holonich, Chief
Uranium Recovery Branch
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
Mail Stop T7J9
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Transmittal of Ground Water Compliance Action Plan and Supporting Background Information for the Ambrosia Lake, New Mexico, Title I UMTRA Site (Subpart B Compliance)

Dear Mr. Holonich:

Enclosed are two copies of the *Ground Water Compliance Action Plan (GCAP)) for the UMTRA Project Site at Ambrosia Lake, New Mexico, May 1998*. Accompanying the GCAP are two 3-ring binders of supporting background information that includes the Site Observation Work Plan and analyses of the most recent field characterization data.

The GCAP is submitted as the 40 CFR 192, Subpart B, ground water modification to the Remedial Action Plan (RAP) and Site Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico (November 1991). The GCAP will serve as replacement of the current text identified in the RAP: Sections 2.0 EPA Standards, Subsection 2.4 Water-Quality Protection, and Section 5.0 Groundwater Protection.

Concurrent with this transmittal, the Department of Energy (DOE) UMTRA Ground Water Project is transmitting copies of the GCAP and supporting background information to the state of New Mexico for approval.

The final *Programmatic Environmental Impact Statement* (PEIS) for the UMTRA Ground Water Project was approved for distribution on September 19, 1996. Distribution of the final PEIS began in October of 1996. The Record of Decision was approved and published in April 1997. In 1998, the DOE Ground Water Project has completed the necessary site-specific National Environmental Policy Act documentation for Subpart B compliance at the Ambrosia Lake Site.

The Ambrosia Lake tailings were stabilized in place, encapsulated within an engineered disposal cell that was constructed to Title I design specifications. The residual radioactive material is managed under the Title I general license. The second part of the two-step general license

AmB 400.02

~~GW AmB1.9~~

RECORD COPY

process (10 CFR 40.27) for the Ambrosia Lake Site will be completed with NRC's concurrence on the GCAP. Further performance assessment monitoring is not required with the selection of the No-Ground-Water Remediation Strategy. The Long-Term Surveillance and Maintenance Project will continue with annual inspections under their long-term care requirements.

Please provide your review comments or approval as soon as possible. If you have questions or need further clarification, call me at (970) 248-7612.

Sincerely,

Donald R. Metzler, P.Hg.
Technical/Project Manager

Enclosures:
GCAP
3-ring binder of supporting documentation

cc w/o enclosures:
M. Layton, NRC
M. Leavitt, NMED
R. Plieness, DOE-GJO
R. Edge, DOE-GJO
File GWAMB ~~1.4~~ (P-Taylor) 1.9

drm\nrcamb.doc

17

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

RECEIVED DOE
JUL 23 1998
GRAND JUNCTION OFFICE

July 17, 1998

Mr. Donald R. Metzler, Project Manager
U.S. Department of Energy
Grand Junction Office
2597 B3/4 Road
Grand Junction, CO 81503

SUBJECT: REVIEW OF AMBROSIA LAKE GROUND WATER COMPLIANCE ACTION PLAN

Dear Mr. Metzler:

The U.S. Nuclear Regulatory Commission (NRC) staff has completed its review of the Ambrosia Lake, New Mexico, Ground Water Compliance Action Plan (GCAP), dated April 1998, which was submitted by a U.S. Department of Energy (DOE) letter dated June 1, 1998. The GCAP reiterates DOE's strategy of "No-Ground-Water-Remediation," based on the ground water in the uppermost aquifer being classified as limited use and, thus, no program to monitor ground water is required.

As discussed in the enclosed Supplemental Technical Evaluation Report (STER), the NRC staff has reviewed the GCAP, and agrees with DOE that the uppermost aquifer does not represent a ground-water resource, because of the limited extent of saturation in the aquifer and its inability to sustain a yield of 150 gallons (570 liters) per day to wells. The uppermost aquifer is expected to return to its premilling and mining condition of little-to-no saturation, further eliminating the unit as a potential future ground-water resource. Ground water does not discharge to the land surface, and the nearest surface water is located approximately 1.5 miles (2.4 kilometers) southwest of the site. No current exposure pathways due to ground-water contamination exist, nor are any foreseen.

Based on the above, the NRC staff concurs with the GCAP. If you have any questions concerning this letter or the enclosed STER, please contact the NRC Project Manager, Ken Hooks, at (301) 415-7777.

Sincerely,

Joseph J. Holonich

Joseph J. Holonich, Chief
Uranium Recovery Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Docket No. WM-67
Enclosure: As stated

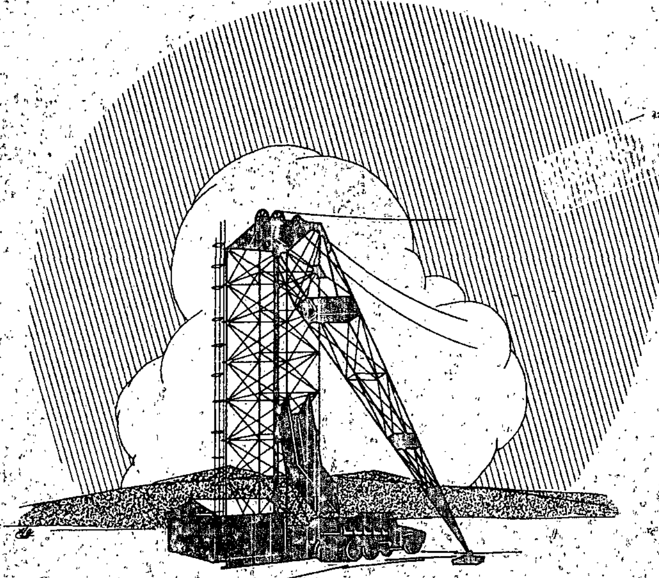
cc: W. Woodworth, DOE Alb
F. Bosiljevac, DOE Alb
E. Artiglia, TAC Alb
M. Leavitt, NMED Santa Fe, NM

SWAMB 1.9

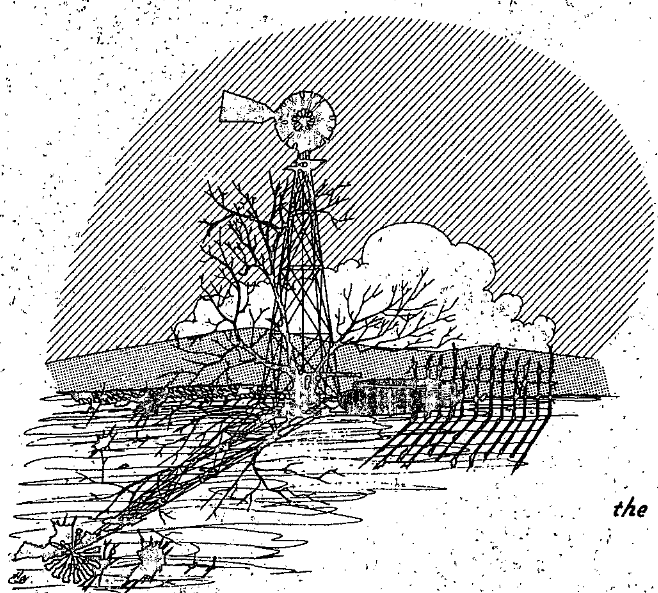
REFERENCES 14-17

TECHNICAL REPORT 35

New Mexico State Engineer
Santa Fe, New Mexico



Geology and Ground-Water Occurrence in Southeastern McKinley County, New Mexico



By
James B. Cooper
&
Edward C. John

Prepared in cooperation with
the United States Geological Survey

TECHNICAL REPORT 35

New Mexico State Engineer
Santa Fe, New Mexico

Geology and Ground-Water Occurrence in Southeastern McKinley County, New Mexico

By
James B. Cooper & Edward C. John

United States Geological Survey

1968

CONTENTS

CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY AND GROUND-WATER OCCURRENCE IN SOUTHEASTERN MCKINLEY COUNTY, NEW MEXICO

By

James B. Cooper and Edward C. John

ABSTRACT

This report describes the geology and ground-water resources of southeastern McKinley County in northwestern New Mexico. This area of about 1,300 square miles is topographically diverse and contains mountains, broad flat valleys, steep escarpments, flat mesas, sloping plains, volcanic cones, lava flows, and solitary buttes. Altitudes of the land surface range from about 6,000 feet to about 9,000 feet. The climate is semiarid; average annual precipitation ranges from 10 to 20 inches, depending on altitude of the land surface. The area contains neither perennial streams nor large permanent bodies of surface water. Most of the area is sparsely populated; mining and ranching are the principal occupations.

Southeastern McKinley County is in the southern part of the San Juan structural basin. Rocks exposed range in age from Permian to Quaternary; the beds dip northward and northeastward, toward the center of the basin, at angles of 3° to 5°. Ground water, commonly under artesian pressure, is yielded to wells from at least 16 distinct aquifers. The principal aquifers in the southwestern part of the area are the Glorieta Sandstone and San Andres Limestone of Permian age and the Chinle Formation of Late Triassic age. The Westwater Canyon Member of the Morrison Formation of Late Jurassic age is the principal aquifer in the central part of the area. Units of the Mesaverde Group of Late Cretaceous age are aquifers in the remainder of the area.

Yields of 300 gallons per minute or more are obtained from wells that tap the aquifer in the Glorieta Sandstone and San Andres Limestone. The other aquifers commonly yield only 5 to 30 gallons per minute to wells; larger yields are obtained locally. Water wells range in depth from 20

feet to more than 1,200 feet. Water levels in wells range from above the land surface to about 800 feet below the land surface. The chemical quality of ground water is variable; most is suitable for livestock and domestic use. The general direction of ground-water movement is downdip to the north and northeast. Recharge to aquifers is from precipitation on the outcrops and from water moving along fault zones. Most aquifers receive only scant recharge directly from precipitation because their outcrop areas are small.

Withdrawals of ground water in southeastern McKinley County were insignificant before 1951. Since that time, mining of uranium ore from the water-bearing Westwater Canyon Member of the Morrison Formation in the Ambrosia Lake and Smith Lake areas has created widespread interest in the occurrence, control, and disposal of ground water associated with the ore. In addition, many new wells were drilled to supply water for uranium-processing mills and housing developments, and to support installations for the mining industry.

INTRODUCTION

Purpose and Scope of Investigation

Southeastern McKinley County, in northwestern New Mexico, is underlain by water-bearing rocks that, in places, contain extensive deposits of uranium ore. Mining of this valuable ore was begun in 1951, thus creating widespread interest in the occurrence, control, and disposal of ground water associated with the ore. Concurrent with the problem of disposing of unwanted ground water in the mines was a large increase in the demand for such water for domestic and industrial use in ore-processing mills and in allied industries near the mining districts.

Prior to the advent of uranium mining and processing, use of water in southeastern McKinley County was primarily for livestock and domestic supplies. The water needs of the ranches were satisfied by small-yield wells widely spaced over the grazing land. Closely spaced wells were found only in a few settlements. Almost no information on the ground-water resources of this area was available to the public.

As a part of the continuing program of investigation of the water resources in the State, southeastern McKinley County was studied by the U.S. Geological Survey in cooperation with the New Mexico State Engineer. The objectives of the investigation were to determine the general availability and chemical quality of ground water, with particular emphasis in those areas where water occurs in strata that contain large bodies of uranium ores, and to determine the principal aquifers, their areal extent, and their areas of recharge and discharge.

The ground-water data contained in this report were obtained by field investigations made between October 1957 and October 1962. Most of the geologic data in the report were obtained from published reports; reconnaissance observations only were made in the field.

Early phases of the field work were restricted mainly to collection of data concerning test wells, exploratory test holes, and mine-shaft excavations. These data were made available by mining companies active in the Ambrosia Lake mining district.

Field work later was extended throughout the area of investigation and consisted of collecting data concerning domestic, stock, and industrial wells from well owners, as well as of locating wells and springs, measuring water levels in wells, and collecting water samples for chemical analysis.

Information about the water-bearing formations was obtained in the field by observation and from logs of wells furnished by well owners and water-well drillers.

The well-inventory and water-sampling phases of the study were completed by E. C. John who joined the project in September 1962. The well-record table, chemical-analysis table, hydrologic map, and parts of the text were prepared by Mr. John.

The report contains records of 230 wells and 27 springs. The chemical quality of the ground water is shown by 121 analyses of water collected from selected wells, springs, and mines. The type and character of the subsurface formations that yield water to wells in the area are indicated by 49 logs of water wells, oil-test wells, and exploratory oil-test drill holes.

Location and Extent of the Area

McKinley County is in the northwest quarter of New Mexico. The southeastern part of the county, described in this report, is an area of about 1,300 square miles adjacent to Sandoval County to the east and Valencia County to the south (fig. 1). A small part of Valencia County which contains the community of San Mateo is also included in the report.

Previous Investigations

A descriptive report of Mount Taylor and the Zuni Plateau is contained in the earliest report of geological investigations in the area (Dutton, 1885). Darton (1928) described the Zuni Mountains and the general stratigraphy of the region. The geology and fuel resources of the sedimentary rocks in the eastern part of the area, near Mount Taylor, were described by Hunt (1936).

A great amount of geologic work has been done in the area since the 1930's by investigators interested primarily in mineral resources such as coal, oil, and uranium. As a result, the surface geology of the entire area has been mapped and described in numerous published reports. Some parts of the area have been studied several times and described in considerable detail. A list of reports dealing with various aspects of the

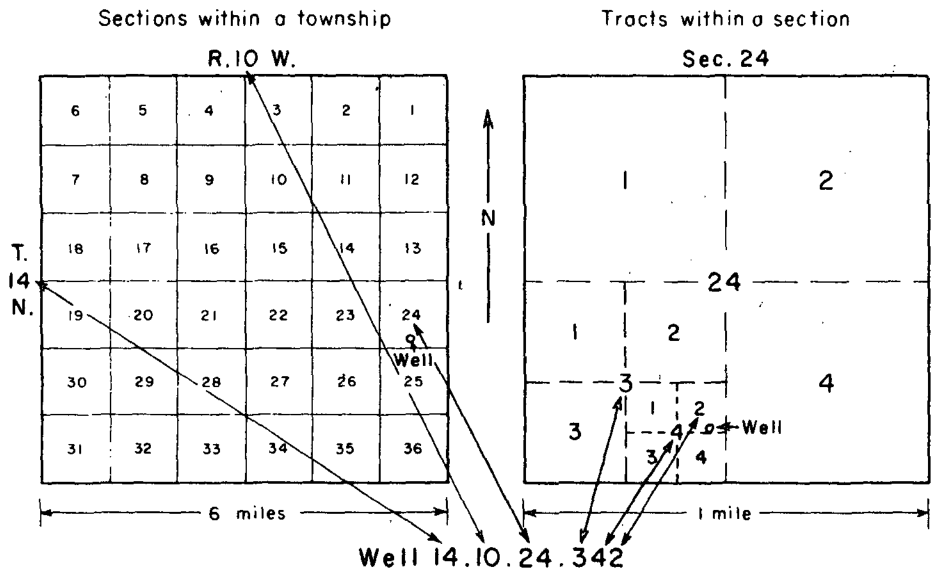


FIGURE 2. -- System of numbering wells in New Mexico.

GEOGRAPHY

Population and Transportation

Southeastern McKinley County is a sparsely populated land used mostly for grazing of cattle and sheep. Vegetation likewise is sparse, and grazing ranges of several thousand acres commonly are used by a single rancher. Temporary camps for herders and ranch workers are scattered over the ranges; however, only a few working ranch headquarters are maintained within the area and many of the ranch operators reside in nearby villages and towns. About 40 percent of the land is privately owned (New Mexico Land Resources Association, 1958), and the largest units are in land grants such as Cebolleta Grant, Bartolome Fernandez Grant, and Ignacio Chavez Grant, all in the eastern part of the area. In the western and northwestern parts, off-reservation Navajo Indian lands total about 300 square miles. The Cibola National Forest, mainly in the southeastern part of the area, accounts for nearly 200 square miles. The remainder of the land, most of which is leased for stock-grazing, is public domain or State owned.

Thoreau and Prewitt, along the main line of the Atchison, Topeka, and Santa Fe Railway and U.S. Highway 66 in the southwestern part of the area in McKinley County, and San Mateo, in Valencia County, are the largest communities. In 1965, Thoreau had an estimated population of 400, San Mateo of 300 (Dinwiddie and others), Prewitt of somewhat less.

Smith Lake, San Antonio Spring, and the Borrego Pass Trading Post are permanent settlements inhabited by Indian missionaries and Indian traders and their families. The community of Marquez in the extreme southeastern part of the area is divided by the McKinley-Sandoval County line (pl. 2).

Several hundred people reside in trailers and temporary housing at and near the mining district of Ambrosia Lake, and trailer courts have been established near Thoreau and Smith Lake.

An Indian population is scattered over the western quarter of the area, and non-Indian families are concentrated near Bluewater Lake, Thoreau, Smith Lake, and Borrego Pass. Only rarely do the Navajo reside in year-round, permanent quarters. Two or more temporary camps, with hogans for shelter, commonly are occupied seasonally in accordance with availability of forage for the flocks of sheep which are the main source of income for the Navajo living in this area.

The population of the Crownpoint census district, which includes the entire eastern half of McKinley County, is given in the 1960 census as 7,271. It is estimated that less than half of that number reside in the area of this investigation.

The nearest major trade centers are Grants in Valencia County and Gallup in McKinley County. Albuquerque, about 100 miles to the east, is the principal cultural and economic center for the area.

The most populous parts of the area are connected by all-weather roads. State Highway 56 crosses the northwestern part of the area and junctions with U.S. Highway 66 at Thoreau. State Highway 53 from San Mateo junctions with ranch road 509 to Ambrosia Lake, and connects with U.S. Highway 66 in Valencia County. The few other roads in the area range from graded gravel-surface to unmarked trails suitable only for travel in good weather by four-wheel-drive vehicles.

Economic Development

According to records of the New Mexico State Inspector of Mines (1962) the value of uranium production in McKinley County in the year ending June 30, 1962, was $57,431,391. Most of the uranium was produced from the 30 or so operating mines, both deep-shaft and incline, at or near Ambrosia Lake, and from a few mines near Smith Lake. More than 2,000 people were employed in the uranium-mining industry.

Two uranium-processing mills are at Ambrosia Lake. The Kermac Mill, operated by the Kermac Nuclear Fuels Corp., employs about 100 people. The Phillips Mill, formerly owned and operated by the Phillips Petroleum Co., employed about 125 persons but was closed in early 1963.

The area produces no other notable minerals. Minor amounts of coal and limestone, sand and gravel, and volcanic cinders for road metal are mined whenever a local market warrants.

contained 2,260 ppm dissolved solids. Sulfate led in concentration; other principal constituents were calcium, sodium, and bicarbonate. Water from well 15.13.12.144, which also taps the Bluff, has a dissolved-solids content of 528 ppm, with only moderate amounts of sodium, bicarbonate, and sulfate. This indicates that potable water is present in the Bluff in the western part of the area.

Recharge to the San Rafael Group is slight in the eastern part of southeastern McKinley County, as the outcrops form steep cliffs with narrow lateral exposure. Outcrops are considerably more extensive in the western part of the area and recharge to the aquifer should be greater. Water in the San Rafael Group moves basinward as indicated by the isolated points of water-level measurement (pl. 2); the amount of natural discharge of water from these formations within the area is not known.

Morrison Formation

Approximately the upper third of the rocks beneath the caprock of Dakota Sandstone that form the escarpments north of U.S. Highway 66 are members of the Morrison Formation. Their areal extent and pattern of outcrop is similar to that of the formations of the San Rafael Group. In ascending order, the members of the Morrison Formation in southeastern McKinley County are the Recapture, Westwater Canyon, and Brushy Basin.

The Recapture Member of the Morrison Formation conformably overlies the Bluff Sandstone of the San Rafael Group. At places, it grades laterally into the Bluff Sandstone and into the overlying Westwater Canyon Member. The Recapture is composed of red-brown, chocolate-brown, light-green, and white interstratified siltstone, shale, and fine sandstone. Sandstone predominates in the upper part of the section where the beds are 5 to 10 feet thick. At places, the Recapture contains conglomeratic, coarse-grained sand, and thin, mottled, red and green limestone. The thickness of the Recapture differs from place to place because it intertongues with underlying and overlying rocks. Near Thoreau, the member is 126 feet thick and at Haystack Mountain it is about 94 feet thick (Rapaport, Hadfield, and Olson, p. 51). Within southeastern McKinley County, the member probably ranges in thickness from about 75 to more than 200 feet. It usually weathers into steep, detritus-covered slopes and, at places, into irregular terrain of pedestal rocks and narrow pinnacles.

The Recapture underlies the area northeast of its outcrop and is 100 to 130 feet thick in the subsurface at Ambrosia Lake.

The Westwater Canyon Member forms steep cliffs above the slope of the Recapture Member and below the slope of the Brushy Basin Member. The Westwater Canyon is a gray to white and light yellow-brown, fine to coarse, poorly sorted sandstone. It is massive and crossbedded and locally contains conglomeratic zones with inclusions of clay, chert pebbles, and small fragments of silicified wood. The member varies in thickness within the area as it interfingers with the Brushy Basin Member and the Recapture Member. One of the sandstone units of the Westwater Canyon, intertonguing with the Brushy Basin Member in this area, has been called the Poison Canyon Sandstone (Zitting and others, 1957, p. 55). This sandstone extends eastward and northeastward from the outcrop of the Westwater Canyon in the Ambrosia Lake area and contains rich deposits of uranium ore.

Outcrop thicknesses of the Westwater Canyon Member reported by Rapaport, Hadfield, and Olson (p. 51) are 166 feet near Thoreau, about 165 feet at Haystack Mountain, and 47 feet in sec. 34, T. 13 N., R. 9 W. North of its outcrop, the Westwater Canyon underlies all of southeastern McKinley County. In the Ambrosia Lake area, the sandstone is 30 to 270 feet thick (Granger and others, 1961, p. 1185).

The Westwater Canyon Member contains extensive deposits of uranium and vanadium ores which are mined in the Ambrosia Lake and Smith Lake areas. The ore is in the sandstone in large masses, tabular bodies, lenses, and thin elongated pods. Near Ambrosia Lake, bodies of ore as thick as 120 feet have been found. The ore deposits may be as much as a mile long and more than 1,000 feet wide. The principal uranium mineral is coffinite, often associated with carbonaceous material, that coats the sand grains or occurs as pellets.

The Brushy Basin Member conformably overlies and intertongues with the Westwater Canyon Member. It is composed of greenish-gray, incompetent, gypsiferous and bentonitic mudstone with yellowish-brown to white, coarse-grained sandstone lenses and a few thin beds of limestone. At places, carbonaceous material is interbedded with the sandstone and mudstone. The Brushy Basin Member weathers into fairly steep slopes. Granger and others (p. 1185) reported that in the Ambrosia Lake area the Brushy Basin ranges in thickness from 62 to 128 feet. However, because of its intertonguing relationships, it may be thinner or thicker locally. Near Thoreau, about 50 feet of the member is exposed and near Smith Lake about 150 feet of section is present in the subsurface.

The sandstone lenses in the Brushy Basin Member contain many deposits of uranium ore. The so-called Poison Canyon Sandstone of the Westwater Canyon Member contains particularly rich deposits. Several mines are on the outcrop of the Brushy Basin and Westwater Canyon Members south of Ambrosia Lake. The member has also been mined at Ambrosia Lake and at Smith Lake.

Only the Westwater Canyon Member of the Morrison Formation is known to be an aquifer in southeastern McKinley County. The Recapture Member is not believed to contain water, except possibly in some of the sandstone units that interfinger with the thick overlying and underlying sandstone units. No wells are known to be finished in the Brushy Basin Member; however, the sandstone units of the Brushy Basin do contain water where they lie below the water table. In sec. 18, T. 15 N., R. 13 W., about 8 miles west of Smith Lake, the lower sandstone lense within the Brushy Basin (the so-called Poison Canyon) contains water in a uranium mine (Hoskins, 1963, p. 49).

In the Ambrosia Lake area and northwestward to Smith Lake, the Westwater Canyon Member is the principal aquifer. The sandstone yields adequate supplies of water for several trailer parks, for minor industrial use, and for stock watering. Most of the ore bodies being mined at Ambrosia Lake are fully or partly saturated and must be drained prior to mining. The Westwater Canyon is a persistent aquifer where it is below the water table. Yields from wells that fully penetrate the aquifer could be expected to exceed 20 gpm.

The chemical quality of the water in the Westwater Canyon Member is good to fair and the water is suitable for domestic, stock, and industrial uses. Analyses of water samples collected from 12 wells and mines (table 3) indicate that the water generally contains less than 1,000 ppm dissolved solids in the Ambrosia Lake and Smith Lake areas. Calcium, sodium, bicarbonate, and sulfate are the main constituents.

Water from wells 14.9.29.312 and 14.11.3.334, which tap the Westwater Canyon, contains 1,410 ppm and 2,310 ppm dissolved solids, respectively. These abnormally high dissolved-solids contents are thought to be due to inflow of water from the overlying Dakota Sandstone. A well drilled into the Westwater Canyon Member should be so constructed that water from overlying aquifers cannot enter the hole.

Water samples collected from the Westwater Canyon Member in seven mines and four wells in the Ambrosia Lake area were analyzed for beta activity and radium (table 3). In all samples beta activity was below the recommended maximum limit; however, the radium concentration in three samples collected from mines and in one sample collected from wells was above the recommended limit for radium in drinking water. An extremely low radium content of 0.2±0.1 pc/l (picocuries per liter) was in the only sample collected from a well (15.12.17.123a) away from the Ambrosia Lake area.

Recharge to the Westwater Canyon is presumably through its outcrop in the western part of the report area; however, the exposures of the sandstone are not extensive. The aquifer may receive recharge from overlying aquifers by downward percolation of water through fault zones. Water in the aquifer is under artesian pressure and water levels in wells rise several tens of feet above the top of the aquifer at most places where it is tapped.

Natural discharge of water from the Westwater Canyon Member in the area is not known. Water in the sandstone, at least in the Ambrosia Lake area where water levels have been measured, moves to the northeast, presumably downdip into the central basin.

Cretaceous System

Rocks of Cretaceous age are exposed in much of southeastern McKinley County; they are covered by basalt flows in the southeastern part of the area and have been removed by erosion in the southwestern part of the area. The strata consist of a thick sequence of marine and continental deposits of shale and sandstone that intertongue, thicken, thin, and change lithology abruptly (fig. 7). The depositional concepts and relationships of these strata are discussed thoroughly in the classic paper on the Cretaceous deposits in the southern part of the San Juan Basin by Sears, Hunt, and Hendricks, (1941, p. 101-121).

about 1,500 feet above the bordering valleys. Many volcanic vents, marked by extinct cinder cones, are scattered over the top of the flat lava cap. Some of these cones are several hundred feet tall and often are clustered in groups. Several separate lava flows, interbedded with pumiceous ash, underlie the surface of the mesa. Well 13.5.7.123 (table 5) penetrated 543 feet of volcanic rocks which include at least seven separate basalt flows. The flows ranged in thickness from about 35 to 75 feet. Interbeds of ash range in thickness from about 5 to 50 feet.

Cerro Alesna, in the northeast corner of the Bartolome Fernandez Grant and a few miles west of the edge of the lava flows, is the most spectacular example of intrusive rock in the area. This volcanic neck is nearly circular and rises 1,200 feet above the surrounding plain. The neck is composed of dense andesite, jointed in nearly vertical columns, and is connected by a dike with outliers of andesite to the southwest.

No wells are known to be finished in volcanic rocks of late Tertiary age in southeastern McKinley County. The extrusive rocks create a large area of recharge for the underlying rocks of Cretaceous age and the intrusive rocks form barriers to the lateral movement of ground water.

Springs (table 2) such as 13.7.11.131 (San Miguel), 13.7.20.121 (San Lucas), 13.7.31.414 (San Mateo), along with numerous unnamed springs, issue from the edges of the sheet basalt flows, either at the contact of the lowest flow with the underlying sedimentary rocks or from the interbeds of ash between the flows. Several of these springs flow 50 gpm or more. San Mateo Springs (13.7.31.414) flow into a reservoir, release from which is used to irrigate farms at San Mateo.

An intrusive dike southwest of Cerro Alesna has created a spring known as Cerro Spring (14.7.10.333) that flows about 10 gpm. Other smaller springs (16.5.15.112 and 16.5.15.233) are along basalt dikes. In years of heavy rainfall, many more springs probably are evident along other dikes in the area.

Tertiary and Quaternary(?) Systems

Basalt flows of late Tertiary and early Quaternary(?) ages overlie rocks of Cretaceous age in the western part of the area a few miles northwest of Thoreau. The basalt occurs as small erosional remnants which cap Mount Powell and an adjacent ridge. The basalt is about 75 feet thick on Mount Powell and may represent several flows (Smith, 1954, p. 20). Source of the basalt at these locations is undetermined. The basalt is not known to contain water.

Quaternary System

Rocks of Quaternary age exposed in southeastern McKinley County consist of basalt flows, alluvium, and landslide and talus materials.

Part of the Bluewater basalt flow covers an area of about 10 square miles along U.S. Highway 66 southeast of Prewitt. The flow originated at El Tintero volcanic crater, near the north edge of the basalt sheet, and it appears to be composed of several alternate layers of vesicular and dense basalt (Gordon, p. 38); near the northwest edge of the flow, well 13.11.27.314 penetrated 30 feet of basalt. Close to the crater, the basalt probably is as much as 200 feet thick. The crest of El Tintero is more than 300 feet higher than the surrounding terrain.

Clay, silt, sand, and gravel of Recent age underlie the major valleys and stream courses, and thin deposits of windblown sand are present at places. The maximum thickness of alluvium within the area is about 150 feet.

Alluvium of Pleistocene age may be present beneath the Bluewater basalt flow. Well 13.11.27.314 (table 5) penetrated 10 feet of brown sand which is probably of alluvial origin and which underlies the basalt and overlies sandy shale.

The landslide and talus materials occupy relatively small patches on the slopes and near the bases of the mesas and escarpments that are capped by sedimentary rocks--in particular by the Dakota Sandstone. Much larger bodies of these slump materials are near the edges of the high, basalt flows northeast of San Mateo.

In southeastern McKinley County, the basalt and landslide debris of Quaternary age do not contain water, and only minor amounts of water are in the alluvium. A few wells yield water from the alluvium along San Mateo Creek and in the valley of Azul Creek. Saturated alluvium may also be present near Ambrosia Lake and Thoreau, although no wells are known to obtain water from the alluvium at these localities. Several dug wells, such as 14.12.20.112 at San Antonio Springs, are in narrow valleys and reentrants throughout much of the area. These dug wells are usually at places where there is surface runoff or direct recharge to the alluvium from underlying sedimentary rocks.

Chemical quality of water in the alluvium depends on source of the water and on the thickness and composition of the aquifer. Well 13.9.22.212, recharged by San Mateo Creek, yields water of good quality containing only 592 ppm dissolved solids (table 3). Well 15.10.32.214, finished in thin alluvium and recharged largely by the underlying Mancos Shale, yields water containing 3,580 ppm dissolved solids, of which 2,550 ppm is sulfate.

GROUND WATER IN THE AMBROSIA LAKE AREA

Development of the large uranium deposits of southeastern McKinley County, principally in the Ambrosia Lake area, increased demand for water both in the mining districts and in the surrounding areas. In the early days of uranium exploration, water was needed by the drilling rigs, and the existing wells were pumped heavily. As the size and importance of the deposits became evident, an influx of people into the area began. Water supplies for trailer camps, for mines, and eventually for milling had to be developed. It became evident during exploration for the uranium that the most promising aquifer in the area was the Westwater Canyon Member of the Morrison Formation of Late Jurassic age, that most of the ore was associated with the Westwater Canyon, and that most of the ore lay within the zone of saturation in the rocks.

The uranium deposits at Ambrosia Lake were mined first at locations where the ore lay above the water table and later-- as information on the conditions of water occurrence became available--at places where the ore lay at deeper levels. Tests were made on wells finished in the Westwater Canyon Member to determine the amount of water within the sandstone, also whether water levels could be lowered, and the sandstone dewatered by pumping from wells, to permit dry mining of the ore.

An aquifer-performance test of the Westwater Canyon Member performed by the Phillips Petroleum Co., using well 14.9.28.234 as the pumped well and well 14.9.28.234a as the observation well, indicated a transmissibility of about 1,300 gallons per day per foot and a storage coefficient of about 0.007. The values obtained from the test are questionable because the pumped well was open only in the lower part of the formation, whereas the observation well was open throughout the formation. Individual water-bearing beds within the aquifer are hydrologically separated by clay lenses; thus, water levels measured in the observation well were composites of the undisturbed water levels from the upper part of the formation and the lowered water levels from the deeper part of the formation. As a consequence, the measurements of drawdown obtained during the test were short on the actual drawdown, and the calculated transmissibility was greater than the actual value.

In addition to testing the Westwater Canyon Member in sec. 28, T. 14 N., R. 9 W., extensive tests of the aquifer were made by various companies in sec. 23 and sec. 25, T. 14 N., R. 10 W., and in sec. 32, T. 14 N., R. 9 W. Because of the low transmissibility of the aquifer, it was determined that dewatering the aquifer by pumping from wells was not feasible. The saturated sandstone interferred with shaft construction and made mining of the ore, within the saturated zone, extremely hazardous.

Quantities of water pumped from various shafts, when the shafts were bottomed in the Westwater Canyon Member, were reported as follows: Phillips "Ann Lee" mine, 365 gpm; Kermac "Section 17" mine, 420 gpm; Kermac "Section 22" mine, 100 gpm; Kermac "Section 24" mine, 400 gpm; Kermac "Section 30" mine, 108 gpm; Kermac "Section 33" mine, 80 gpm; Homestake-Sapin Partners "Section 23" mine, 475 gpm; Homestake-Sapin Partners "Section 25" mine, 725 gpm. Data on other mines are not available, although mines in the eastern part of the area are reported to have yielded larger amounts of water owing to the greater depth of the water-bearing formations, and fractures caused by faulting and folding of the formations. The "Sandstone" mine shaft reportedly yielded 890 gpm from the middle bed of sandstone of the lower part of the Mancos Shale, and the "Rare Metal" mine shaft reportedly yielded 2,000 gpm from the same zone. Water pumpage from the Homestake-Sapin Partners "Section 23" mine and "Section 25" mine amounted to 1 billion gallons and 2.6 billion gallons, respectively, during the period October 1958-September 1962. Early pumpage from the mines yielded much more water than did later pumpage, probably a reflection of dewatering of the aquifer and interference of the cones of depression formed in the piezometric surface. At the "Ann Lee" mine, Phillips Petroleum Co. reports that inflow to the shaft from the Dakota Sandstone is mostly from the updip side, indicating that the sandstone has been drained almost to the level of the shaft on the downdip side. Similar conditions can be expected to occur in all the mines if activity continues over a long period of time.

The volume of water encountered during mining was not the major problem. The wetted mass of saturated rock was hard to load because the muck had many properties of a viscous fluid. Once in the mine car or skip, the water drained away and the loose muck then became a compact mass that adhered to the car or skip, creating dumpage problems. Also, the fine sand that remained suspended in the water wore out loading equipment and sump pumps. Drainage of the work areas before mining became the answer to the wet-muck problem and also created safer working conditions, as the drained rock had greater strength than the wet rock. Jenkins (1959) and Stoehr (1959) describe the drainage methods, wet-rock problems, and solutions.

A suitable water supply for milling of the ore also was a problem in the early phase of mining at Ambrosia Lake. Deep wells were drilled near the two mill sites to test the aquifers; however, these wells were not used because of the poor chemical quality of the water and the relatively small yields. Water for milling ultimately was obtained from the mines themselves.

Much of the water pumped from the mines is channeled into a formerly dry arroyo that carries the effluent southward out of the Ambrosia Lake area. The arroyo joins San Mateo Creek near the junction of State Highways 53 and 334. Flow in the arroyo to San Mateo Creek has been continuous for several years. In San Mateo Creek, the water flows southwestward for several miles before sinking into the alluvium.

In the Ambrosia Lake area, the mining problems created by water in the ore zones have largely been solved and--temporarily, at least--the problem of a source of water for ore processing also has been solved. However, if mining continues a long time, water in the Westwater Canyon Member may be depleted locally and ore-process water may have to be obtained from other sources. Also, since the start of pumpage from the mines, at least one domestic well near the mines has had to be deepened. If this trend continues, the Westwater Canyon Member may no longer be an adequate aquifer and water supplies for domestic and stock use may have to be obtained from the underlying Bluff Sandstone.

QUALITY OF WATER

Ground water in southeastern McKinley County is of suitable chemical quality for stock use, and most of it is acceptable for domestic use. Chemical analyses of 121 ground-water samples are given in table 3. The

EPA 906/9-75-002

WATER QUALITY IMPACTS OF URANIUM MINING AND MILLING ACTIVITIES IN THE GRANTS MINERAL BELT, NEW MEXICO

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION VI, DALLAS, TEXAS 75201

September 1975

EPA 906/9-75-002

IMPACT OF URANIUM MINING AND MILLING ON WATER QUALITY IN THE GRANTS MINERAL BELT, NEW MEXICO

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION VI, DALLAS, TEXAS 75201

September 1975

TABLE OF CONTENTS

Purpose and Scope

In September 1974, Mr. John Wright of the New Mexico Environmental Improvement Agency requested that the staff of EPA Region VI assist in implementing a survey of the uranium mining and milling activities of the Grants Mineral Belt to determine the impact of these activities on surface and ground water in the area.

The objectives outlined for the survey were:

1. Assess the impacts of waste discharges from uranium mining and milling on surface and ground waters of the Grants Mineral Belt.

2. Determine if discharges comply with all applicable regulations, standards, permits and licenses.

3. Evaluate the adequacy of company water quality monitoring networks, self-monitoring data, analytical procedures and reporting requirements.

4. Determine the composition of potable waters at uranium mines and mills.

5. Develop priorities for subsequent monitoring and other follow-up studies.

In response to the request by the New Mexico Environmental Improvement Agency, plans were developed to conduct a joint, cooperative study involving Region VI, EPA; the Office of Radiation Programs - Las Vegas Facility (ORP-LV); the National Enforcement Investigation Center, Denver (NEIC-Denver), and the New Mexico Environmental Improvement Agency (NMEIA).

A reconnaissance was conducted in January 1975 to view the study areas, meet with mining/milling company officials, and plan the data collection effort. Sample collection began in late February 1975, and was completed in early March 1975. Laboratory analyses for trace metals, gross alpha, radium-226 analysis and other radiological analyses were completed in July 1975.

Study Results

The details of the study are presented in two reports which are appended to this summary report: Surface Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico, and Ground-Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt, New Mexico.

Based on the data collected and analyzed, the following conclusions and recommendations were developed.

SUMMARY AND CONCLUSIONS

I. TASK: Assess the Impacts of Waste Discharges from Uranium Mining and Milling on Surface and Ground Waters of the Grants Mineral Belt.

1. Ground water is the principal source of water supply in the study area. Extensive development of ground water from the San Andres Limestone aquifer occurs in the Grants-Bluewater area where the water is used for agriculture, public water supply, and uranium mill feed water. Development of shallow, unconfined aquifers in the alluvium also occurs in this area. Principal ground-water development in the mining areas at Ambrosia Lake, Jackpile-Paguate, and Churchrock is from the Morrison Formation and, to a lesser extent, from the Dakota Sandstone or the Tres Hermanos Member of the Mancos Shale. The Gallup water supply is derived primarily from deep wells completed in the Gallup Sandstone using well fields located east and west of the urban area and 11 kilometers north of the city.

2. In proximity to the mines and mills and adjacent to the principal surface drainage courses, shallow ground-water contamination results from the infiltration of (1) effluents from mill tailings ponds; (2) mine drainage water that is first introduced to settling lagoons and thence to watercourses, and (3) discharge (tailings) from ion exchange plants. In the case of the Anaconda mill, seepage from the tailings ponds and migration of wastes injected into deep bedrock formations is observed in the San Andres Limestone and in the alluvium, both of which are potable aquifers. With the exception of seepage from the Kerr-McGee Section 36 mine in Ambrosia Lake, significant amounts of wastewater from the remaining mines and mills probably does not return to known bedrock aquifers. Deterioration of water quality results from conventional underground mining as a result of penetration or disruption of the ore body. The most dramatic changes are greatly increased dissolved radium and uranium. Induced movement of naturally saline ground water into potable aquifers is also likely but undocumented. Similarly, the ground-water quality impacts of solution (<u>in situ</u>) mining are unknown.

3. The Grants, Milan, Laguna, and Bluewater municipal water supplies have not been adversely affected by uranium mining and milling operations to date. For the Grants and Milan areas, chemical data from 1962 to the present indicate that near the Anaconda mill some observation wells have increased slightly in total dissolved solids, sulfate, chloride and gross alpha but domestic wells have generally remained unchanged. Projections made in 1957 of gross nitrate deterioration of ground water have not been substantiated by subsequent data. Of the municipal supply wells in the study area, the Bluewater well bears additional monitoring because of its location relative to the Anaconda tailings ponds.

4. Contamination of the Gallup municipal ground-water supply by surface flows, consisting mostly of mine drainage, has not occurred and is extremely unlikely because of geologic conditions in the well field and the depth to productive aquifers. Another well field north of the City will, in no way, be affected by the drainage.

5. With the exception of the area south and southwest from the United Nuclear-Homestake Partners mill, widespread ground-water contamination from mining and milling was not observed in the study area. Throughout the study area widespread contamination of ground water with radium was not observed despite concentrations of as much as 178 pCi/l in mine and mill effluents. Radium removal is pronounced, probably due to sorptive capacity of soils in the area. In the vicinity of the Anaconda mill, radium and nitrate concentrations in the alluvial aquifer decline with distance from the tailings ponds, but neither parameter exceeds drinking water standards.

6. Ground water in at least part of the shallow aquifer developed for domestic water supply downgradient from the United Nuclear-Homestake Partners mill is contaminated with selenium. Alternative water supplies can be developed using deep wells completed in the Chinle Formation or in the San Andres Limestone. Potential well sites are located in the developments affected or in the adjacent area. A third alternative includes connecting to the Milan municipal system. Further evaluations are necessary to determine the best course of action.

7. Mining practices, per se, have an adverse effect on natural water quality. Initial penetration and disruption of the ore body in the Churchrock mining area increased the concentration of dissolved radium in water pumped from the mines from 0.05 - 0.62 pCi/l to over 8 pCi/l. According to company data, the concentration rose to over 75 pCi/l, or at least 75 times the natural concentration in the two-year period during which the mine was being developed. The pattern of increasing radium with time, also seen in Ambrosia Lake, is being repeated. Ground-water inflow via long holes in the Kerr-McGee Section 36 mine contain a relatively low concentration of dissolved radium-226. Therefore, much of the radium loading of mine effluent is apparently a result of leaching of ore solids remaining from mucking and transport within the mine. In some cases, this could be reduced by improved mining practices such as provision of drainage channels along haulage drifts.

8. Radium concentrations in Arroyo del Puerto, a perennial stream, exceed New Mexico Water Quality Criteria as a result of discharges from the Kerr-McGee ion exchange plant and Section 30W and 35 mines, and from the United Nuclear-Homestake Partners ion exchange plant. Selenium and vanadium concentrations exceed EPA 1972 Water Quality

8. (Continued)

Criteria for use of the water for irrigation and livestock watering, and render the stream unfit for use as a domestic water source.

9. Company data show that seepage from the Anaconda tailings pond at Bluewater averages 183 million liters/year (48.3 million gallons) for 1973 and 1974. The average volume injected for the same time period was 348 million liters/year (91.9 million gallons). Therefore, approximately one-third of the total effluent volume remaining after evaporation (531 million liters/year) enters the shallow aquifer, which is a source of potable and irrigation water in Bluewater Valley. From 1960 through 1974, seepage alone introduced 0.41 curies of radium to the shallow potable aquifer. Adequate monitoring of the movement of the seepage and the injected wastes is not underway.

10. There are indications that waste injected into the Yeso Formation by the Anaconda Company are not confined to that unit as originally intended in 1960. Three nearby monitoring wells, completed in the shallower San Andres Limestone and/or the Glorieta Sandstone, show a trend of increasing chloride and uranium with time. Positive correlations of water quality fluctuations with the volumes of waste injected are a further indication of upward movement. The absence of monitoring wells in the injection zone is a major deficiency in the data collection program.

11. Rainfall and runoff at the Anaconda Jackpile Mine erode uranium- and selenium-rich minerals into Rio Paguate. This erosion can be mitigated by waste stabilization and runoff control.

12. The maximum concentration of radium observed in shallow ground water adjacent to the Kerr-McGee mill at Ambrosia Lake was 6.6 pCi/l. According to company data, seepage from the tailings ponds occurs at the rate of 491 million liters/year (130 million gallons/year). This is 29 percent of the influent to the "evaporation ponds" and attests to their poor performance in this regard. Radium and gross alpha in the seepage are 56 pCi/l and 112,000-144,000 pCi/l, respectively. Total radium introduced to the ground water to date is estimated at 0.7 curies. Wells completed in bedrock and in alluvium, and located near watercourses containing mine drainage and seepage from tailings ponds, contain elevated levels of TDS, ammonia, and nitrate. One well, which contained 1.0 pCi/l in 1962 now is contaminated with 3.7 pCi/l of radium. Sorption or bio-uptake of radium is pronounced, hence concentrations now in ground water are not representative of ultimate concentrations.

13. Water-quality data from 11 wells over a 200-square kilometer area in the Puerco River and South Fork Puerco River drainage basins reveal

13. (Continued)

essentially no noticeable increase in concentrations of radionuclides or common inorganic and trace constituents in ground water as a result of mine drainage. Natural variations in the uranium content of sediments probably account for differences in radium content in shallow wells. Dissolved radium in shallow ground water underlying stream courses affected by waste water is essentially unchanged from areas unaffected by mine drainage. None of the samples contained more than recommended maximum concentrations for radium-226, natural uranium, thorium-230, thorium-232, or polonium-210 in drinking water. However, the paucity of sampling points and the absence of historical data make the foregoing conclusion a conditional one, particularly in the reaches of the Puerco River within approximately 10 kilometers downstream of the mines.

14. Four wells sampled in the vicinity of the Jackpile mine near Paguate contained 0.31 to 3.7 pCi/l radium-226. With the exception of the latter value from the new shop well in the mine area, remaining supplies contain 1.7 pCi/l or less radium. The Paguate municipal supply contains 0.18 pCi/l. None of the wells were above maximum permissible concentrations (MPC) for the other common isotopes of uranium, thorium, and polonium. Ground water from the Jackpile Sandstone may contain elevated levels of radium as a result of mining activities. Mine drainage water ponded within the pit contained 190 pCi/l radium and 170 pCi/l of uranium in 1970. The impacts of mining on groundwater quality downgradient from the mining area are unknown due to the lack of properly located monitoring wells. No adverse impacts from mining on the present water supply source for Paguate are expected.

15. Of the 71 ground-water samples collected for this study, a total of 6 had radium-226 in excess of 3 pCi/l PHS Drinking Water Standard. Two of the 6 involved potable water supplies. One containing 3.6 pCi/l serves a single family and is located adjacent to Arroyo del Puerto and downgradient from the mines and mills in Ambrosia Lake. The second contains 3.7 pCi/l and is used as a potable supply for the labor force in the new shop at the Jackpile Mine.

16. The highest isotopic uranium and thorium, and polonium-210 contents for any potable ground-water supplies sampled in the study area are less than 1.72% of the total radionuclide population guide - MPC as established in NMEIA regulations.

17. The lowest observed concentration (background levels) in ground water are summarized as follows:

17. (Continued)

Radionuclides	Range (pCi/l)	Average (pCi/l)
Radium-226	0.06 - 0.31	0.16
Polonium-210	0.27 - 0.57	0.36
Thorium-230	0.013 - 0.051	0.028
Thorium-232	0.010 - 0.024	0.015
U-Natural	14 - 68	35

18. The uranium isotopes (uranium 234, 235 and 238) are the main contributors to the gross alpha result; however, in several determinations, gross alpha underestimated the activity present from natural uranium.

19. No correlation was found between gross alpha content of 15 pCi/l (including uranium isotopes) and a radium-226 content of 5 pCi/l.

20. It is doubtful that the gross alpha determination can even be used as an indicator of the presence of other alpha emitters (e.g. U-natural and polonium-210); and since the gross alpha results have such large error terms, no meaningful determination of percentage of radionuclides to gross alpha can be implied.

21. Gross alpha determinations also failed to indicate the possible presence of lead-210 (primarily a beta emitter) which, because of the lower MPC of 33 pCi/l, may be a significant contributor to the radiological health hazard evaluation of any potable water supply.

22. Radium-226 in ground water is a good radiochemical indicator of waste-water contamination from mines and mills. Due to the low maximum permissible concentration, it also provides a good means for evaluating health effects. Selenium and nitrate also indicated the presence of mill effluents in ground water. Polonium-210, thorium-230 and thorium-232 concentrations in ground water fluctuate about background levels and are poor indicators of ground-water contamination from uranium mining and milling activities.

23. For routine radiological monitoring of potable ground-water supplies, isotopic uranium and thorium and polonium-210 analyses do not appear to be necessary due to their high maximum permissible concentrations (chemical toxicity of uranium may be a significant limiting factor, however).

VII. STREAM SURVEYS

When the mines and mills were evaluated, selected stream stations were sampled to determine the effect of mine and mill discharges on water quality. The New Mexico Water Quality Standards limit the radium concentration in surface streams to a maximum of 30 pCi/l. Data on the samples collected from surface streams are provided in Table 3.

ARROYO DEL PUERTO

Arroyo del Puerto receives waste from the United Nuclear-Homestake Partners and Kerr-McGee ion-exchange plants and from Kerr-McGee Section 30W and 35 mines. There is no flow in the creek upstream of these discharges.

Radium-226 concentrations of samples collected downstream from the Kerr-McGee mill were from 45 to 50 pCi/l. These concentrations not only violate the New Mexico Water Quality Standards, but exceed the AEC criteria (30 pCi/l) for radium in water discharged to an unrestricted environment. Radium concentrations in Arroyo del Puerto decreased near the mouth to levels ranging from 6.1 to 7.2 pCi/l. This decrease is due to the adsorption of radium on sediment and/or vegetation. During periods of heavy run-off, the radium concentration can be expected to increase due to scouring of the stream bed.

The selenium concentration of Arroyo del Puerto downstream from the Kerr-McGee mill was 0.15 mg/l, decreasing to 0.04 mg/l near the mouth. Vanadium concentrations in Arroyo del Puerto near the Kerr-McGee mill averaged 0.8 mg/l, increasing to 1.1 mg/l near the mouth. Selenium and

Table 3

SUMMARY OF ANALYTICAL DATA
FOR
SURFACE WATER SAMPLING

:ion Description	Number of Samples	Gross Alpha (pCi/l) Max.	Min.	Avg.	Radium-226 (pCi/l) Max.	Min.	Avg.	Uranium (mg/l) Max.	Min.	Avg.	Selenium (mg/l) Max.	Min.	Avg.	Vanadium (mg/l) Max.	Min.	Avg.
ıyo del Puerto downstream :err-McGee Mill	3	1,700	1,400	1,500	50	45	47	12	5.0	7.7	0.16	0.13	0.15	1.0	0.6	0.8
ıyo del Puerto near the mouth	3	1,500	750	1,100	7.2	6.1	6.5	6.6	4.7	5.8	0.07	0.01	0.04	1.9	0.5	1.1
Mateo Creek ighway 53 Bridge	1	-	-	1,000	-	-	1.09	-	-	4.7	-	-	0.02	-	-	<0.3
Puerco downstream of chrock Mines	3	500	470	490	2.60	0.97	2.04	5.0	3.8	4.2	0.07	0.03	0.04	0.6	0.5	0.6
Puerco upstream ingate Plant	3	510	720	440	1.63	0.36	0.81	4.8	3.7	4.2	0.01	0.01	0.01	0.9	0.3	0.6
Puerco at Highway 666 Bridge	3	350	210	260	0.42	0.09	0.22	2.5	1.7	2.0	<0.01	<0.01	<0.01	0.6	0.3	0.5
Paguate at Paguate	1	-	-	2.8	-	-	0.11	-	-	<0.02	-	-	<0.01	-	-	0.6
Moquino upstream of pile Mine	1	-	-	11.2	-	-	0.17	-	-	<0.02	-	-	<0.01	-	-	1.8
Paguate at Jackpile Ford	1	-	-	270	-	-	4.8	-	-	1.2	-	-	<0.05	-	-	0.5
Paguate at Paguate rvoir Discharge	1	-	-	230	-	-	1.94	-	-	1.1	-	-	<0.01	-	-	0.6
San Jose at Interstate Bridge	1	-	-	38	-	-	0.37	-	-	0.10	-	-	<0.01	-	-	0.3

vanadium have harmful effects when present in high concentrations in water used for irrigation or livestock watering. The 1972 EPA Water Quality Criteria (Committee on Water Quality Criteria, 1972) suggests that irrigation waters not exceed 0.02 mg/l selenium and 0.1 mg/l vanadium, while livestock waters should not exceed 0.05 mg/l selenium and 0.1 mg/l vanadium. On this basis, Arroyo del Puerto is rendered unfit for irrigation and livestock watering by the uranium mining discharges throughout its entire length. This is contrary to New Mexico Water Quality Standards which require that discharges not render a water unfit for a beneficial use.

The flow of Arroyo del Puerto enters San Mateo Creek where the entire flow enters the aquifer within three miles of the confluence. This recharge adds a large loading of radium and selenium to the ground water. Ground-water evaluations by ORP-LVF will address this question.

RIO PUERCO

The Rio Puerco receives drainage from Kerr-McGee and United Nuclear Corporation Churchrock mines. Samples collected downstream from these discharges contained a maximum radium-226 concentration of 2.6 pCi/l [Table 3]. The concentration decreased to 0.4 pCi/l at the town of Gallup. These concentrations meet the New Mexico Water Quality Criteria of 30 pCi/l, as well as the PHS Drinking Water Standard of 3 pCi/l for radium-226. Selenium concentrations downstream from the mine discharges ranged from 0.03 to 0.07 mg/l for an average of 0.04 mg/l, or four times PHS Drinking Water Standards. The selenium concentration decreased downstream to 0.01 mg/l at the Wingate plant and to less than detection limits at Gallup.

LA-6839-MS Copy 2
Informal Report

22

UC-11
Issued: June 1977

Geology and Hydrology in the Vicinity of the Inactive Uranium Mill Tailings Pile, Ambrosia Lake, New Mexico

W. D. Purtymun
Caroline L. Wienke
David R. Dreesen

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT W-7405-ENG. 36

CONTENTS

TABLES

FIGURES

GEOLOGY AND HYDROLOGY IN THE VICINITY OF THE INACTIVE URANIUM MILL TAILINGS PILE, AMBROSIA LAKE, NEW MEXICO

by

W. D. Purtymun, Caroline L. Wienke, David R. Dreesen

ABSTRACT

A study was made of the geology and hydrology of the immediate area around a uranium mill at Ambrosia Lake, New Mexico. The mill was in operation from June 1958 through April 1963 and produced 2.7×10^9 kg of tailings. The possible environmental consequences of this inactive tailings pile must first be delineated so that stabilization needs and future stabilization success can be properly assessed.

The Ambrosia Lake area is underlain by over 1000 m of alternating shales, siltstones, and sandstones that dip gently to the northeast into the San Juan Basin. Water-bearing sandstones make up less than 25% of this sedimentary section. Water quality in the sandstones is fair to poor, with total dissolved solids ranging from 500 to over 2000 mg/ℓ.

The present total volume of tailings is estimated at 1.5×10^6 m^3 and ranges in thickness from about 1 to 10 m. The tailings pile is underlain by the Mancos shale which dips to the northeast. The shale is about 120 m thick with three interbedded silty sandstones that are about 9 m in thickness. One of these sandstones outcrops beneath the western part of the pile; the eastern part of the pile is underlain by shale. Ground water in the shales and sandstones beneath the pile is recharged by runoff north of the pile and from three ponds located north, northeast, and east of the pile. The movement of water in shale and sandstones is to the southwest. Secondary recharge to the water in the shales and sandstone is from the basin within the tailings pile. Water in the southeast part of the tailings basin is forming a ground water mound above the underlying sediments.

The major transport mechanisms of tailings and possible contaminants from the pile include wind erosion, surface water runoff, movement of ground water beneath the pile, and gaseous diffusion from the pile (radon).

I. INTRODUCTION

The Ambrosia Lake area is a major producer of uranium in the United States. The uranium is used as fuel in nuclear reactors to produce energy in the form of electricity. Uranium is recovered by several milling processes which generate wastes in the form of mill tailings. The tailings are confined in areas adjacent to mills by a series of dikes that retain the slime-sand-water mixture. These tailings piles constitute a potential source of contaminants to air, water, soil, and biota.

The Los Alamos Scientific Laboratory (LASL) is conducting a study to determine the possible environmental consequences of such a tailings pile, so that optimum stabilization can be proposed and the degree of its success documented. This particular pile was selected because it is no longer in use. It is located in the Ambrosia Lake Mining District in northwestern New Mexico, about 40 km north of Grants (Fig. 1). The tailings in this pile were produced from milling about 2.7 × 10^9 kg of uranium ore, from June 1958 to April 1963, by the Phillips Petroleum Company. United Nuclear Corporation purchased the mill in March 1963 and closed the mill permanently the next month.[1]

A LASL engineering survey was conducted of the pile during May 1976, and a general reconnaissance

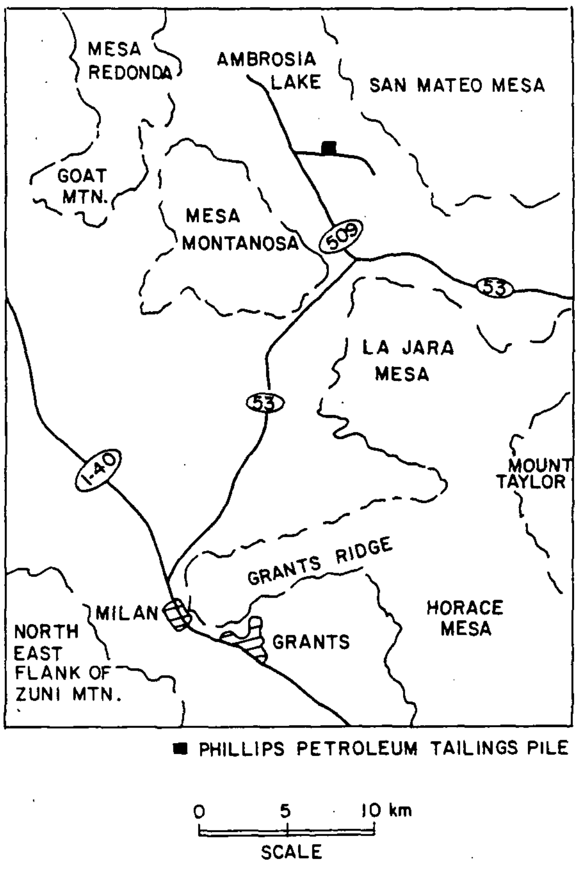


Fig. 1.
Location of the Phillips Petroleum Company tailings pile.

has been made of the immediate area. Literature searches were conducted on uranium ore milling procedures and on the geology and hydrology of the area. Test drilling was conducted in July 1976 to delineate groundwater and physical characteristics in, and adjacent to, the pile. The drilling was a joint effort of LASL and Ford, Bacon and Davis, Utah Inc, Salt Lake City, Utah. The latter were under contract to the Energy Research and Development Administration (ERDA) for an independent study of inactive uranium mill tailings piles.

This report describes the geohydrologic regime of the area and provides support for continuing studies related to the identification and inventory of contaminants in the pile, the distribution and effects of contaminants in the adjacent ecosystems, and transport mechanisms of contaminants from the pile. Contents include an outline of the regional geology and hydrology, physical characteristics of the tailings pile, and the local geologic and hydrologic conditions of the pile and the adjacent area. Five appendices are attached; Appendix A consists of geologic logs in the area; Appendix B contains water quality data related to mines and an active mill tailings pile monitoring net; Appendix C is the LASL engineering survey; Appendix D contains geologic logs, well construction, and hydrologic data resulting from test drilling in July 1976; and Appendix E presents diagrammatic maps of the original land surfaces, topography on top of the pile, and water levels in shales and sandstone beneath the pile.

II. REGIONAL GEOLOGY AND HYDROLOGY*

The area of study is about 9.6 by 14.4 km and is within the southern part of the Ambrosia Lake Mining District (Fig. 2). It is a northwest to southeast trending valley cut into shales of Cretaceous age. Sandstones with some interbedded shales of Cretaceous age form the edges of the valley to the east and west. Test holes in the area have

*The regional geology and hydrology presentation is taken in part from reports by Barr,[2] Cooley,[3] Cooper and John,[4] Craig et al.,[5] Freeman and Helpert,[6] Gordon,[7] Harshbarger et al.,[8] Hunt,[9] Kelley,[10-11] Sears et al.,[12] Smith,[13] and Young and Ealy.[14]

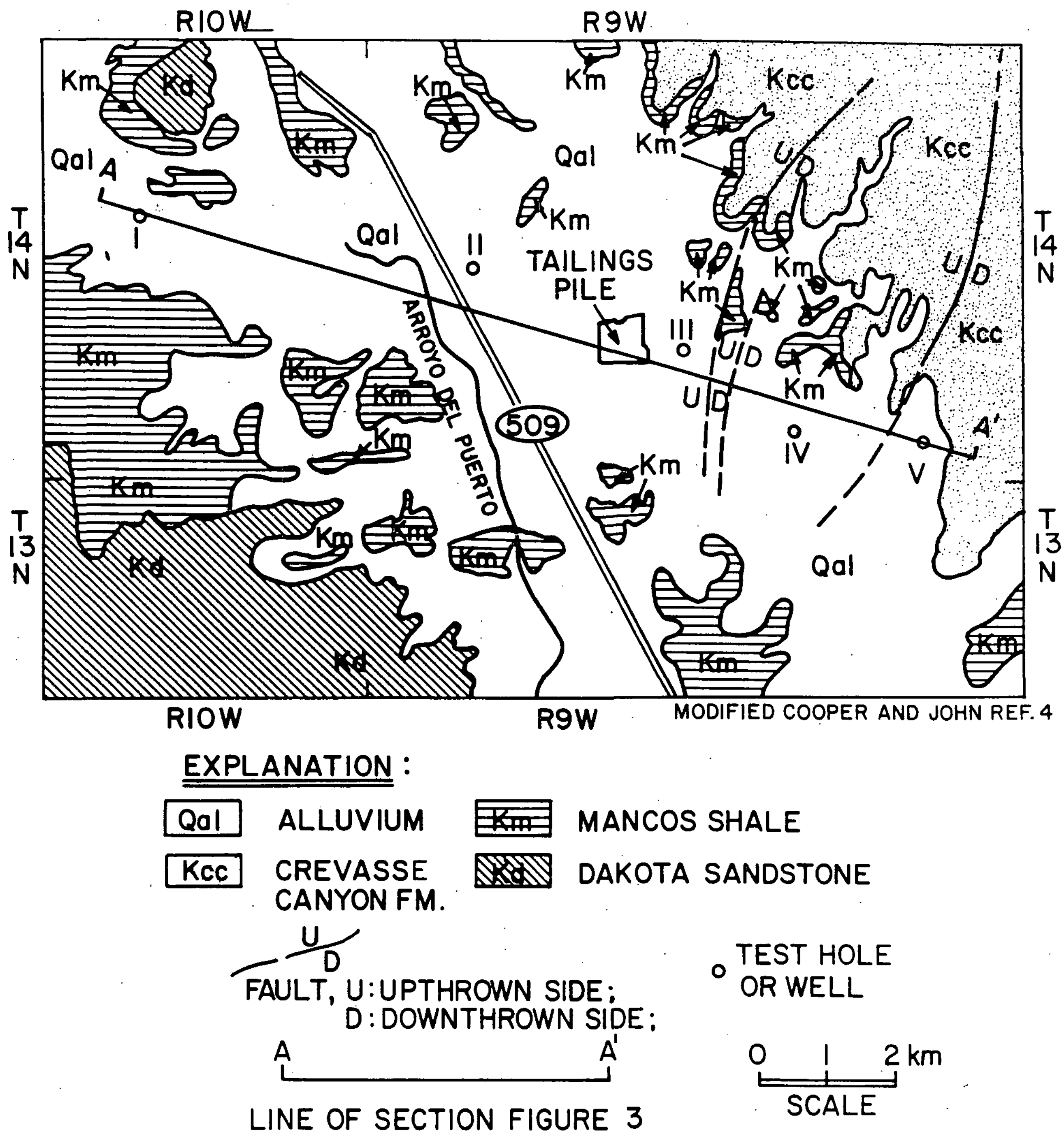


Fig. 2.
Geologic map of the Ambrosia Lake area.

penetrated rocks, oldest to youngest, from Permian through Cretaceous (Appendix A). Alluvium of Quaternary age has developed in, and adjacent to, the drainage channels.

Prior to the development of mines and mills, stream flow in the major channel, Arroyo del Puerto, was intermittent; however, since mining and milling development, it is reported that perennial flow occurs due to seepage from active mill sites and from mine dewatering operations.[4] The major aquifer in the area occurs in rocks of Cretaceous age with aquifers of lesser importance in rocks of Permian and Jurassic ages.

A. Geology

A brief description is made of the lithology and thickness of geologic formations in outcrops or penetrated by test holes. The presentation is made from the oldest to youngest formation, i.e., rocks of Permian, Triassic, Jurassic, and Cretaceous ages.

Geologic units of Permian age penetrated by test holes are the Glorieta Sandstone and the overlying San Andres Limestone (Appendix A).[2] The Glorieta Sandstone is a white to yellowish gray, thick-bedded-to-massive sandstone with some siltstone in the lower part. The thickness of the formation penetrated by one test hole is about 16 m. The San Andres Limestone is a light gray limestone with some sandy limestone and limey sandstone lenses. The unit is thick-bedded-to-massive. The thickness reported in the area is about 34 m.

The rocks of Triassic Age are the Chinle Formation and the overlying Wingate Sandstone.[3] The lower part of the Chinle is a thin-bedded, fine-grained, purple to white silty sandstone with some massive brown to purple beds of siltstone and mudstone. The middle part is a medium to thick-bedded, yellow to gray, hard sandstone with some lenses of pebbly conglomerate. It contains some petrified wood and is cross bedded with minor partings of purple to gray siltstone and mudstone. The upper part of the Chinle is red to brown or purple siltstone and mudstone with thin sandstone lenses and limestone beds. The Chinle Formation is about 443 m thick. The Wingate Sandstone is a massive cross-bedded, reddish brown to orange sandstone with a regional thickness of about 18 m.

Rocks of Jurassic age overyling the Wingate Sandstone are the San Rafael Group and the Morrison Formation.[8] The San Rafael Group is composed of four members which in ascending order are the Entrada Sandstone, the Todilto Limestone, the Summerville Formation, and the Bluff Sandstone. The Entrada Sandstone is a red, silty to fine-grained massive sandstone in the lower section which is overlain by a massive, reddish orange to pink, fine-grained, cross-bedded sandstone. The thickness penetrated by two test holes in the area is 30 and 40 m. The Todilto Limestone overlies the Entrada and is a greenish to dark gray, fine-grained, thin-bedded limestone. There has been some uranium mined from this formation south of Ambrosia Lake. The thickness ranges from 9 to 13 m. Overlying the Todilto is the Summerville Formation. The Summerville is a reddish brown to light green and white, fine-grained sandstone with lenses of siltstone and shale. The thickness ranges from 99 to 102 m in this area. The uppermost member of the San Rafael Group is the Bluff Sandstone, a gray to light brown, fine-grained massive, cross-bedded sandstone. The thickness in the area ranges from 30 to about 90 m.

The Morrison Formation of Jurassic age is composed of three members which, in ascending order, are the Recapture Member, the Westwater Canyon Member, and uppermost Brushy Basin Member.[5,6,8] The Recapture Member is a reddish brown to light green and white siltstone with some shale and sandstone lenses. The thickness in the area ranges from 29 to about 45 m. The Westwater Canyon Member is a gray to white and light yellow-brown, fine- to coarse-grained, poorly sorted sandstone. The sandstone is massive, cross-bedded, and locally contains conglomerate lenses as well as clay chert pebbles and inclusions of petrified wood fragments. The Westwater contains extensive deposits of uranium and vanadium ores and is the primary source of the mill tailings pile investigated. It is also the principal aquifer of the area. The thickness ranges from 44 to about 60 m. The uppermost Brushy Basin Member is a greenish gray mudstone with some lenses of white to brown, coarse-grained sandstone and a few thin beds of limestone. The thickness ranges from 29 to 52 m.

Rocks of Cretaceous age are, in ascending order, the Dakota Sandstone, Mancos Shale, and Crevasse Canyon Formation.[9,12] The Dakota Sandstone is a light brown to gray, massive sandstone with local beds and lenses of conglomerate and carbonaceous material near the base. The sandstones are cross-bedded in the upper section. The thickness of the Dakota ranges from 18 to 24 m. The Dakota Sandstone outcrops along the southwestern edge of the area (Fig. 2). The overlying Mancos Shale forms the floor of the valley and in places is covered by a thin veneer of alluvium. The Mancos Shale is a thick lithologic unit composed of dark gray, calcareous, fissile clay of marine origin. Interbedded with the shale are four sandstone beds, each generally less than 9 m thick. The upper surface of the shale is cut away by erosion in the valley, with thicknesses reported from test holes ranging from 52 to 158 m. East of the San Mateo Fault the shale is about 310 m thick on the downthrown side of the fault (Fig. 3). The Phillips mill tailings pile sits directly on this shale. The overlying Crevasse Canyon Formation is composed of shale, claystone, siltstone, minor seams of coal, and tan sandstone. The formation outcrops in the northeastern part of the area and is not considered important to the study (Fig. 2).

Quaternary alluvium occurs along the Arroyo del Puerto and in low areas and depressions in the valley. The alluvium is derived from the Crevasse Canyon Formation and the Mancos Shale and is composed of tan to gray silts, sands, gravels, and a few cobbles and boulders of sandstone. The alluvium may in part be worked by water and in places consists of wind-laid sand. The thickness ranges from a veneer to as much as 30 m.

B. Geologic Structure

The Ambrosia Lake area is underlain by sedimentary rocks to depths greater than 1000 m. These rocks are part of the structural element known as the Chaco Slope, a part of the southern extension of the San Juan Basin. The highlands south of the Chaco Slope, the Zuni Uplift, have flexed the sedimentary rocks so that the general regional dip of these units is northward and north-eastward across the Chaco Slope into the San Juan Basin. There is little if any structure in the southern part of the Ambrosia Lake area except the general dip of the sedimentary beds to the northeast at 1 to 3 degrees. The older rocks (Dakota Sandstone) outcrop on the southwestern edge of the area, while the younger rocks (Crevasse Canyon Formation) outcrop to the northeast (Fig. 2). Two close spaced, north-south trending normal faults in the central part of the area are downthrown to the east (Figs. 2 and 3). The largest fault, the San Mateo Fault, occurs along the eastern edge of the area and is downthrown to the east about 150 m.

C. Hydrology

Major drainage through the Ambrosia Lake area is the southeastern trending Arroyo del Puerto that is a tributary of San Mateo Creek. Perennial flow in Arroyo del Puerto occurs with the release of water pumped from the mines and seepage from active mill tailings ponds. The flow extends to San Mateo Creek where it is lost to evaporation and infiltration into the underlying rocks. The gradient on Arroyo del Puerto is low and the arroyo tends to meander, thus, large areas of marsh grasses, sedges, and cattails occur along the channel. Evapotranspiration in these areas reduces a large percentage of the flow during the summer months. Stream flow losses into the Mancos shale are probably quite small; however, losses are greater where the channel is cut on sandstone units of the Mancos Shale or the Dakota Sandstone near the southern edge of the area (Fig. 2). Minor amounts of recharge to these sandstones occur from stream flow in the arroyo.

The principal aquifer in the Ambrosia Lake area is the Westwater Canyon Member of the Morrison Formation. Other aquifers of lesser importance occur in the Glorieta Sandstone, San Andres Limestone, the Bluff Sandstone, the Dakota Sandstone, and sandstone in the Mancos Shale.[4]

These aquifers are principally sandstone and lie between shale or relatively impermeable rocks. Of the 1000-m section of sediments underlying the tailings pile, about 25% are permeable sandstones and 75% are relatively impermeable shales or combinations of sediment. The sedimentary rocks outcrop to the south and southwest and dip gently into the central basin to the north and northeast. Recharge to these sandstone aquifers occurs along these outcrops, principally in some of the deeper beds on the flanks of the Zuni Uplift where precipitation is much greater than in the Ambrosia Lake area. With the predominance of shale lying on and between the sandstone aquifers, recharge to the aquifers is mainly through outcrops.

The water in the aquifer moves downdip, thus wells penetrating these water-bearing units are under artesian pressure with the shales overlying the sandstones acting as confining layers. When the shale and sandstone is penetrated by a test hole, water in the sandstone will rise in the bore hole until it reaches a static level. There may be some vertical leakage from sandstones through joint fractures or faults. Also, faults which displace the sedimentary rocks may act as ground-water boundaries to restrict the movement of water or as conduits to distribute the water from water-bearing beds to other permeable units. Boundaries may increase or decrease artesian pressures in the aquifer causing irregularities in the piezometric surface of the aquifer (imaginary surface representing the static

TABLE I

CHEMICAL AND RADIOCHEMICAL QUALITY OF WATER
(U. S. Geological Survey, Ref. 4)

Geological Unit and Use	Location*	Date	SiO_2 (mg/ℓ)	Ca (mg/ℓ)	Mg (mg/ℓ)	Na (mg/ℓ)	Na + K (mg/ℓ)	K (mg/ℓ)	HCO_3 (mg/ℓ)	CO_3 (mg/ℓ)	SO_4 (mg/ℓ)	Cl (mg/ℓ)	F (mg/ℓ)	NO_3 (mg/ℓ)	TDS (mg/ℓ)	Hard as $CaCo_3$ (mg/ℓ)	Specific Conductance (μmho/cm)	pH	Beta (pCi/ℓ)	^{226}Ra (pCi/ℓ)
Mancos Shale																				
Domestic	J	10-62	6	3	2	1120		0.1	194	85	1940	76	2.5	5.8	3340	15	4610	9.6	---	---
Dakota Sandstone																				
Mine Water	1	8-62	16	71	27	356		6.5	296	0	772	14	0.5	0.2	1410	290	1980	7.5	---	---
Mine Water	1	4-63	20	140	56	276		7.6	319	0	850	17	0.3	1.0	1525	162	2065	7.7	18	2.7
Mine Water	3	10-57	---	---	---		188		335	0	506	6	0.5	0.5	---	402	1440	8.0	---	---
Mine Water	7	5-63	18	102	33	200		4.2	340	0	500	25	0.4	0.7	1050	278	1490	7.6	75	27
Westwater Sandstone																				
Mine Water	1	8-62	18	29	6	172		6.0	275	0	230	9	0.7	0.1	606	98	926	7.7	---	---
Mine Water	2	4-63	14	25	9	178		6.2	300	0	222	8	0.6	0.2	611	100	904	8.0	37	5.6
Mine Water	3	10-57	---	---	---		150		287	0	119	7	0.6	0.3	---	44	697	8.1	---	---
Mine Water	4	5-63	14	20	7	136		7.8	249	0	164	5	0.3	0.2	478	80	742	8.1	12	2.0
Mine Water	5	2-58	16	6	<1	145		2.4	238	4	123	6	0.4	<0.1	426	16	667	8.3	49	42.0
Mine Water	6	4-63	14	15	5	226		3.7	252	0	322	8	0.3	0.2	718	58	1103	8.2	9	1.4
Mine Water	7	4-63	19	53	13	252		5.2	209	0	536	9	0.9	0.3	945	172	1360	7.8	6	1.2
Mine Water	8	8-62	22	30	10	119		6.2	243	0	158	8	0.8	3.9	477	116	729	7.6	---	---
Mine Water	9	4-63	16	32	17	90		7.4	247	0	136	6	1.0	<0.1	437	150	692	7.8	56	2.3
Mine Water	10	8-59	16	34	16		111		253	0	165	8	0.6	0.1	---	151	745	8.0	---	---
Mine Water	11	8-59	12	36	16		181		285	0	293	6	0.3	<0.1	---	154	1060	---	---	---
Domestic	A	10-62	15	90	26	485		5.6	253	0	1110	22	1.1	1.2	1880	332	2520	7.9	---	---
Domestic	B	12-56	16	59	24	186		4.8	314	0	381	7	0.5	<0.1	834	240	1230	7.6	69	1.1
Domestic	C	10-59	16	211	62	127		4.2	256	0	794	10	0.6	15.	1410	782	1710	7.8	39	10.0
Domestic	D	8-59	10	46	12	114		7.6	220	0	218	8	0.4	<0.1	512	164	796	7.3	18	1.1
Domestic	F	3-57	16	15	7		169		230	0	212	13	1.0	4.6	551	66	858	8.2	---	---
Domestic	H	9-56	---	---	---	---		---	533	0	262	10	---	---	633	302	945	7.9	---	---
Domestic	I	9-56	---	---	---	---		---	306	0	306	11	---	---	721	240	1090	7.7	---	---
Bluff Sandstone																				
Domestic	E	10-60	13	26	4	700		3.6	168	4	1360	60	2.4	1.1	2260	81	2830	8.3	---	---
Glorieta Sandstone																				
	G	11-66	23	262	94		373		531	0	1030	242	0.6	0.6	2370	1040	3100	6.7	---	---

*See Fig. 4 for location.

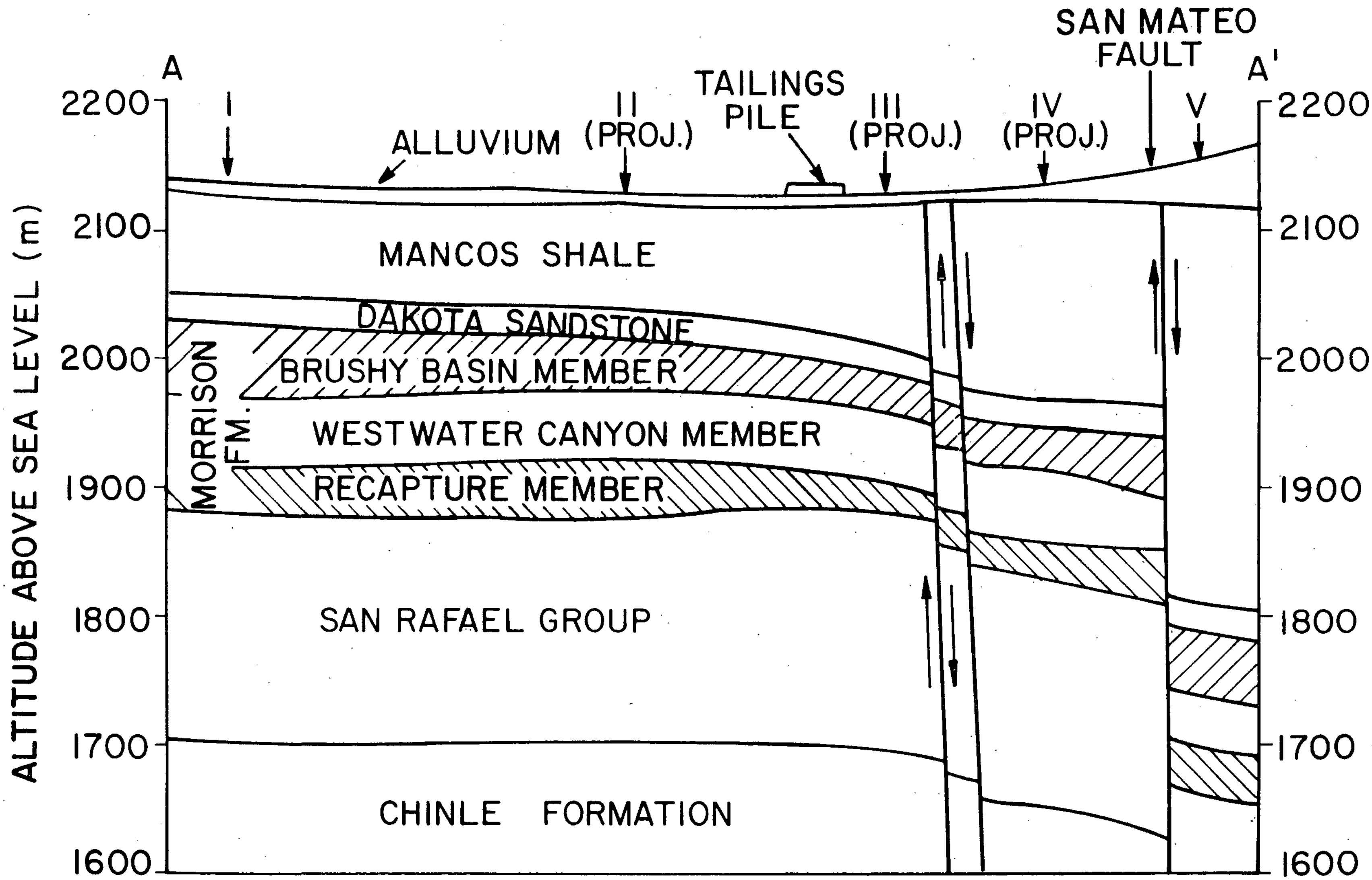


Fig. 3.
Geologic cross section showing geologic units beneath the pile (for location see Fig. 2).

head of ground water). The artesian pressures are not great enough to cause flowing wells in the Ambrosia Lake area.

The Glorieta Sandstone and San Andres Limestone are considered as a single aquifer. Two test holes were drilled into these formations in the Ambrosia Lake area at depths of 890 and 940 m. The formations have yields adequate for a small water supply (<4 ℓ/s); however, this water is of very poor quality. Chlorides were reported at 240 mg/ℓ, sulfates at 1000 mg/ℓ, and total dissolved solids at 2400 mg/ℓ (Table I, for location see Fig. 4).

The Bluff Sandstone contains a small amount of ground water, but generally is not used due to poor quality, depth to water, and low yield (<1 ℓ/s). Test holes in the Ambrosia Lake area penetrated the Bluff at depths of 250 and 252 m. Chlorides are 60 mg/ℓ, sulfates 1360 mg/ℓ, and total dissolved solids 2260 mg/ℓ (Table I).

The Westwater Canyon Member of the Morrison is the major producer of uranium ore and is the principal aquifer in the Ambrosia Lake area, supplying the water for domestic and industrial uses. The ore bodies being mined are fully or partly saturated. An aquifer test, using a pumped well and an observation well in the Westwater (Log III, Appendix A), indicated a transmissivity of 120 m^2/day and a storage coefficient of 0.007. These values are considered greater than the actual values due to partial penetration of the Westwater by the observation well.[4] Other wells tested in the area indicated low transmissivities, so that during the development of mines in the Westwater Canyon it was not feasible to dewater the ore bodies by pumping from wells.[4] The ore bodies were dewatered during mining operations. During 1962 the pumping rate from eight mines in Westwater Canyon ranged from 5 to 46 ℓ/s.

Contours of the piezometric surface of water in the Westwater Canyon Member show a slight ground-water mound that trends west to east (Fig. 5). Since the water is under artesian pressure, these contours do not coincide with the top of the

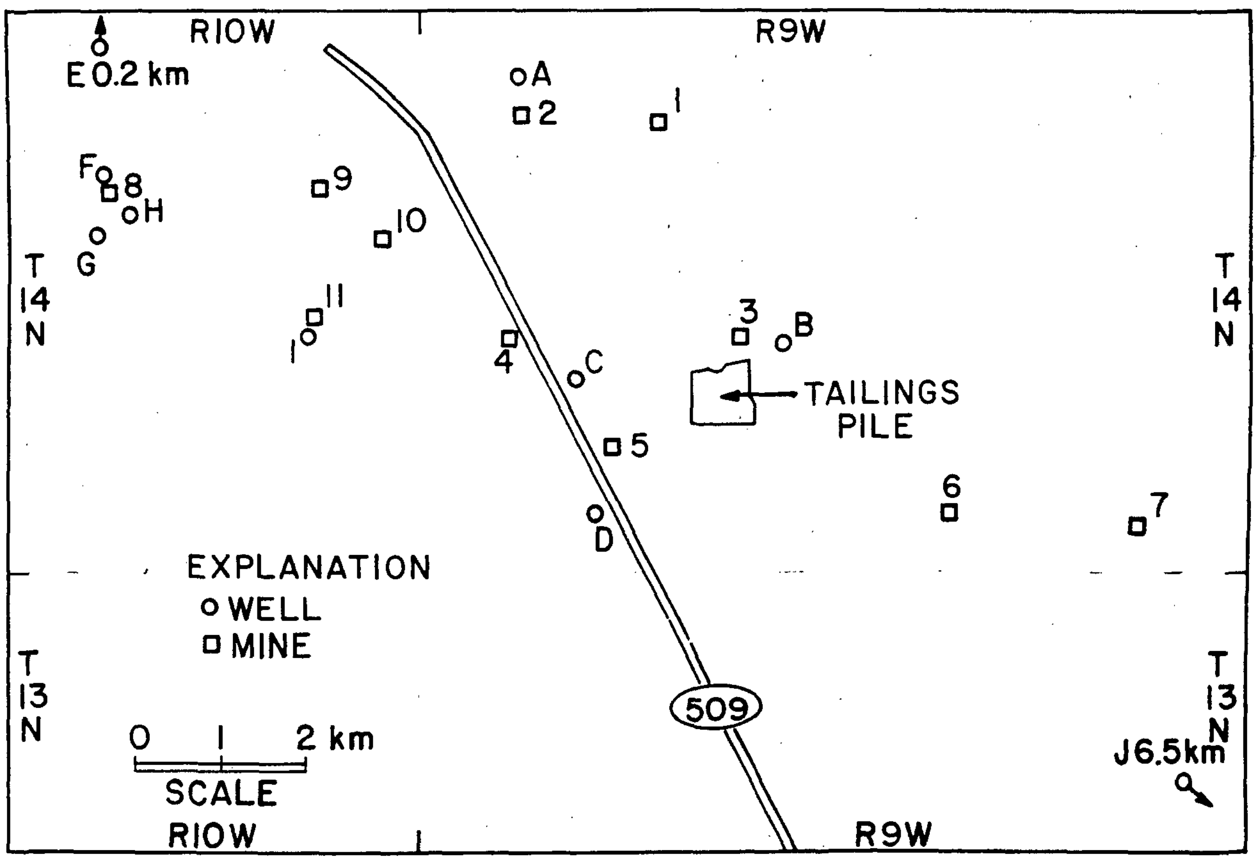


Fig. 4.
Generalized locations of water quality data from wells and mines.

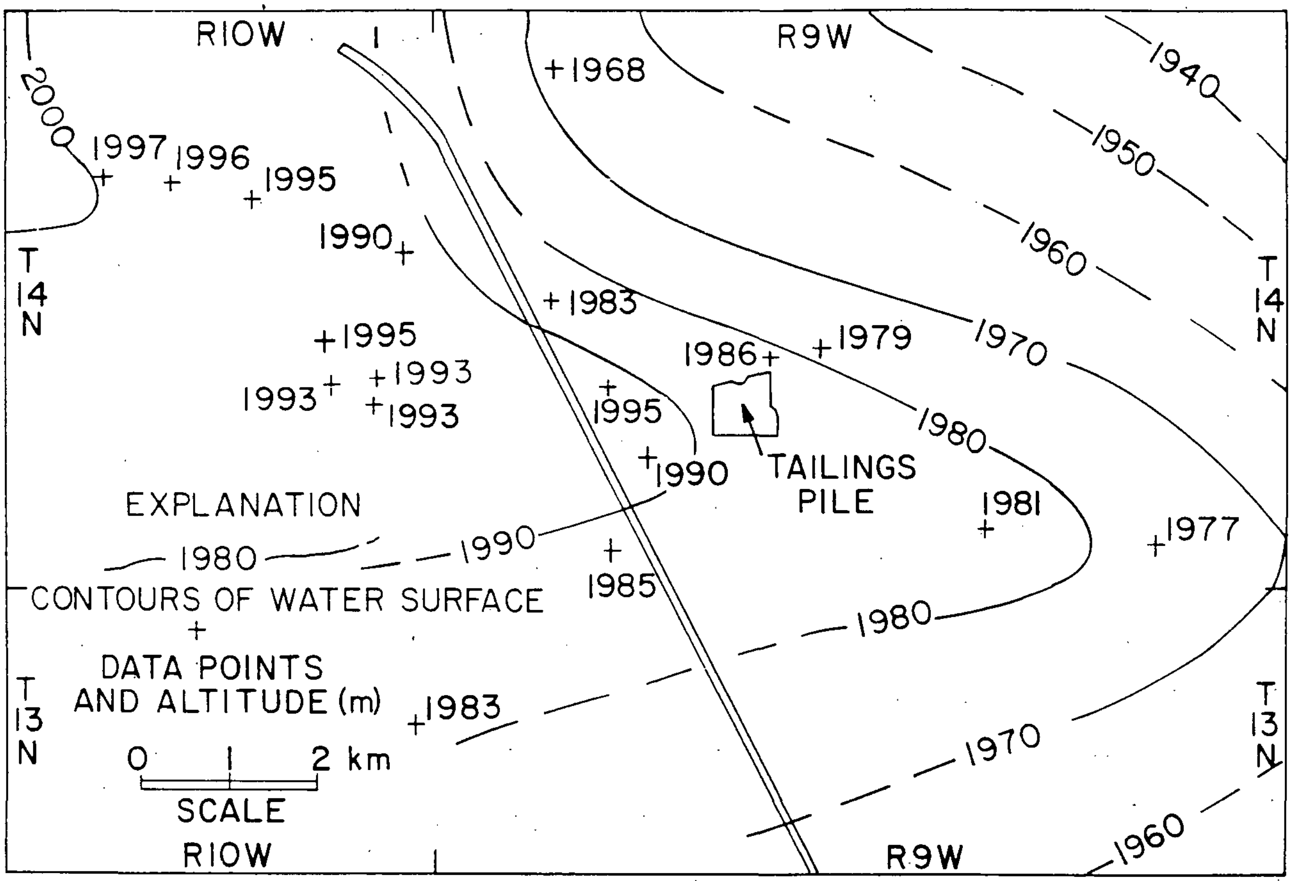


Fig. 5.

Contour of the piezometric surface of water in the Westwater Canyon Member.

Westwater Canyon Member. The ground-water mound indicates differential artesian pressures in the aquifer. It may be a coincidence; however, the mound shows the same general trend as the ore bodies in Westwater Canyon.[15]

Dewatering of the ore bodies over the past 20 yr has removed a large volume of water from the Westwater Canyon Member. Some of this water is used for mining and milling. Several of the mines are using the water for secondary recovery by solution mining. The water is pretreated, injected into low-grade deposits, and recovered through bore holes. It is then processed to recover uranium from the solution. The quality of water is better than that found in other aquifers in the area, but is undesirable for domestic use (Table II). Gross-beta activity for both mine pumpage and domestic supply ranged from 6 to 69 pCi/ℓ while ^{226}Ra ranged from 1.1 to 42 pCi/ℓ (Table I). Trace elements in pumpage from mines in the Westwater Canyon Member were analyzed in 1976 (Appendix B).

The Dakota Sandstone contains small quantities of ground water and generally yields <1 ℓ/s. In the mine shaft nearest the tailings pile (Fig. 4) the inflow was from the updip side of the shaft indicating the sandstone had been drained to the level of the shaft on the downdip side.[4] The sulfates in the water are quite high (Table III). Gross-beta measurements in water from the Dakota Sandstone were 18 and 75 pCi/ℓ while ^{226}Ra concentrations were 2.7 and 27 pCi/ℓ for the two samples analyzed (Table I).

The shale units of the Mancos Shale are not considered aquifers due to low permeability and poor quality of water. The sandstone lenses interbedded with the shales do contain some water, but due to the silty character of the sandstone and limited thickness do not yield large volumes of water. The quality of water is poor, as indicated by the one

TABLE II

RANGE IN CONCENTRATIONS FOR SULFATES, CHLORIDES, AND TOTAL DISSOLVED SOLIDS FOR MINE DRAINAGE AND DOMESTIC SUPPLY[a]

	No. of Analyses	Sulfate (mg/ℓ)		Chloride (mg/ℓ)		Total Dissolved Solids (mg/ℓ)	
		Min	Max	Min	Max	Min	Max
Mine Water	11	119	536	6	9	437	611
Domestic	7	212	1110	7	22	512	1880

[a]Complete analyses are given in Table I.

TABLE III

RANGE IN CONCENTRATION OF SELECTED CHEMICALS IN WATER FROM MINE DRAINAGE[a]

mg/ℓ

Sulfates		Chlorides		Total Dissolved Solids	
Min	Max	Min	Max	Min	Max
500	850	6	25	1050	1410

[a]Four samples, complete analyses are given in Table I.

analysis in the area. Sulfate was 1940 mg/ℓ, chloride 76 mg/ℓ, and total dissolved solids 3340 mg/ℓ (Table I).

III. PHILLIPS PETROLEUM COMPANY MILL TAILINGS PILE

The Phillips Petroleum Company mill tailings pile is located near the center of the Ambrosia Lake Mining District (Fig. 1). The ore processed at the Phillips Petroleum Company mill consisted, at least in part, of ore mined from the adjacent mine. The specific uranium mineral present in this ore is assumed to have been coffinite, $U(SiO_4)_{1-x}(OH)_{4x}$.[16] Other sandstone ores from the Ambrosia Lake area contain uraninite, $(U^{+4}_{1-x}, U^{+6}_{x})O_{2+x}$ and carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 1\text{-}3H_2O$, as well as coffinite.[17] Ore processed at the Phillips Petroleum Company mill during its 5-yr period of operation is reported to have averaged 0.23% U_3O_8.[17]

Uranium was extracted from the ores using a carbonate leaching process in which the alkaline mill solutions were continuously recirculated, regenerated with caustic soda for uranium precipitation, and recarbonated with CO_2 and soda ash as required. The uranium was leached from the ores in pressurized Pachuca tanks. The waste was separated from the uranium in the leach solution in three stages of drum filters and then pumped to the tailings pile.[1]

A. Physical Characteristics

The tailings pile is located west of the mill building (Fig. 6). Access to the top of the pile can be made by vehicle from ramps located on the east-central, south-central, and the southwest corner of the pile.

The tailings consist of clays, silts, very fine sand, and fine sand-size particles described in the milling process as "slimes." The slimes, containing fluids and chemicals used in the process, account for 20-25% volume of the tailings.[18,19,20] The remaining portion of the tailings is made up of medium-to-coarse sand-size particles described as sands. They account for 75 to 80% of the volume. The tailings were pumped as a slurry to the tailings pile. Four dikes were built to hold the slurry pumped from the mill. The slurry was discharged through pipes placed along the inner side of the dikes. The sands settled out first near the points of discharge next to the dikes while the fluids and slimes accumulated in the

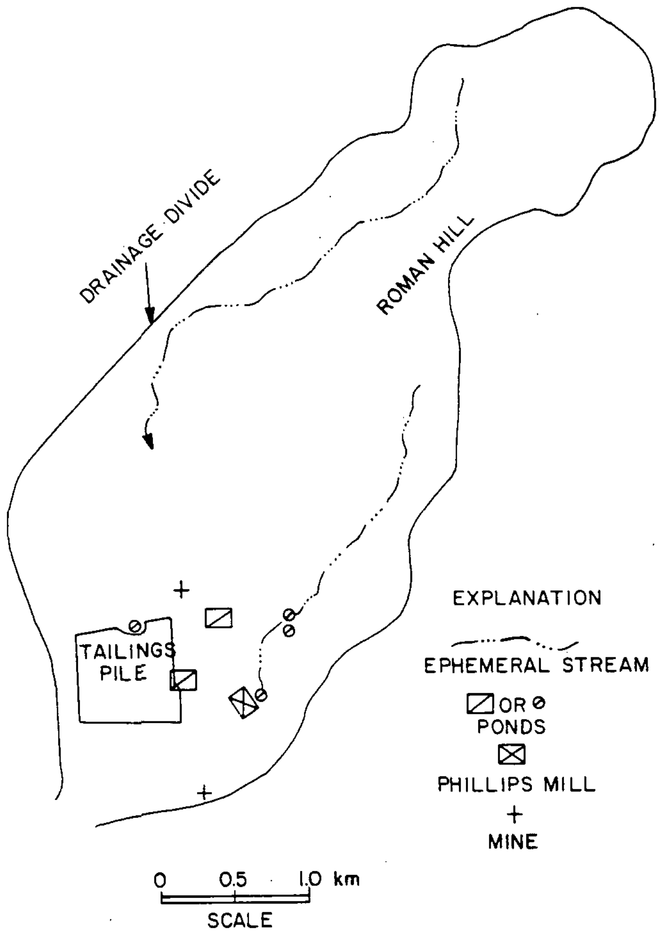


Fig. 6.
Drainage area showing location of ephemeral stream, ponds, mill, and mines in relation to tailings pile.

depression between the dikes. As the diked area neared capacity, a second tier of dikes was constructed along the southern and western edges of the pond. If a second tier was constructed along the eastern edge, it is not obvious since wind-deposited tailings have covered the dike. The northern dike, consisting of only one tier, is composed of shale and silty sandstone, as are the first-tier dikes on the southern and western side of the pile. The second-tier dike on the southern and western side appears to have been constructed in part with tailings and in part with shale and silty sandstone. The average height of the southern dike (2 tiers) is about 9 m while the north dike (1 tier) averages 4 m in height. The height of the dikes on the east and west decreases gradually to the north.

A topographic survey was made of the tailings pile and adjacent area in May 1976 (Appendix C). The pile is roughly a square, about 620 m on a side, with a surface area of about 3.7×10^5 m^2. Contours of the surface of the tailings pile reveal a shallow basin with the lowest point located in the south-central portion of the pile (Fig. 7). The relief from the low area to the northern edge of the dike is about 9 m while the relief to the eastern, southern, and western edges of the dike is about 3 to 4 m. The total volume that the basin will hold to the "spill point" is estimated at 3×10^5 m^3, as derived from contours (Fig. 7 and Appendix E).

The thickness of the tailings pile was determined using the depth at which it became difficult to drive four well points into the pile (Appendix D), the surveyed elevations adjacent to the pile (Appendix C), and the field interpretation of gamma logs in six test holes.[21] Based on this data, a map was prepared showing the topography of the original land surface underlying the pile (Fig. 8 and Appendix E). The contours show a depression beneath the southeastern corner of the pile that becomes less pronounced to the north. Other than this depression, there is little evidence of a large amount of shale or silty sandstone removed from beneath the pile. Some sediments were removed to the south and west of the pile which were probably used for dikes.

An isopach (thickness) map of the tailings was prepared (Fig. 9) using the topographic contours on top of the tailings pile (Fig. 7) and contours on the original land surface (Fig. 8). The thicker section of tailings coincides with the depression in the southeast corner and along the dikes on the southwest. In these areas the tailings are about 10 m thick and decrease to less than 1 m to the northeast and 2 m to the northwest. Integrating area with thickness, the volume of the tailings in the pile is estimated at 1.5×10^6 m^3. The volume of the earthfill dike that projects into the basin was excluded from the calculation.

About 2.7×10^9 kg of mill tailings were released into the pile during the operation of the mill. It has been reported that 0.36×10^9 kg were removed and used as mine fill, leaving an estimated 2.3×10^9 kg in the pile.[17] The bulk density of the tailings has been estimated at 1.6 g/cm^3.[20] Based on this density and 2.3×10^9 kg of tailings material, the volume of tailings in the pile is 1.4×10^6 m^3. This compares favorably with the volume calculated from the isopach map (Fig. 9).

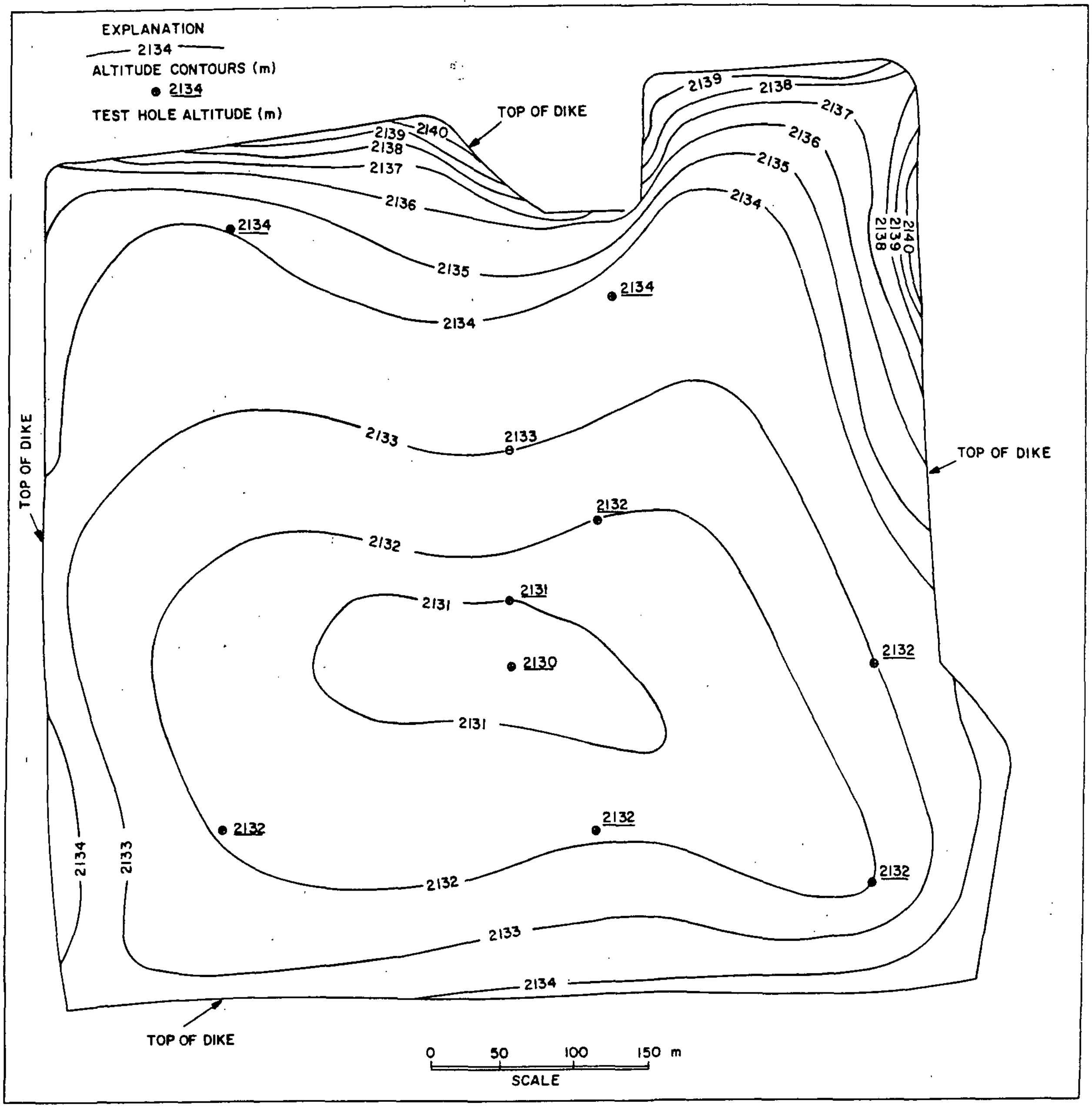


Fig. 7.
Topographic contours of the tailings pile.

B. Surface Water Runoff and Ponds

The rim rock along the edges of the valley is covered with some piñon and juniper; vegetation in the valley floor is desert grassland. Salt grasses and sedges are found along the channel of the Arroyo del Puerto. The ponds adjacent to the mill tailings pile support some sedges and cattails, while the larger pond northeast of the pile supports a dense growth of salt cedar.

The climate of the area is semiarid. The annual average precipitation is about 25 cm, more than one-half of which occurs from late June to mid-September.[22] As a result of high insolation, low

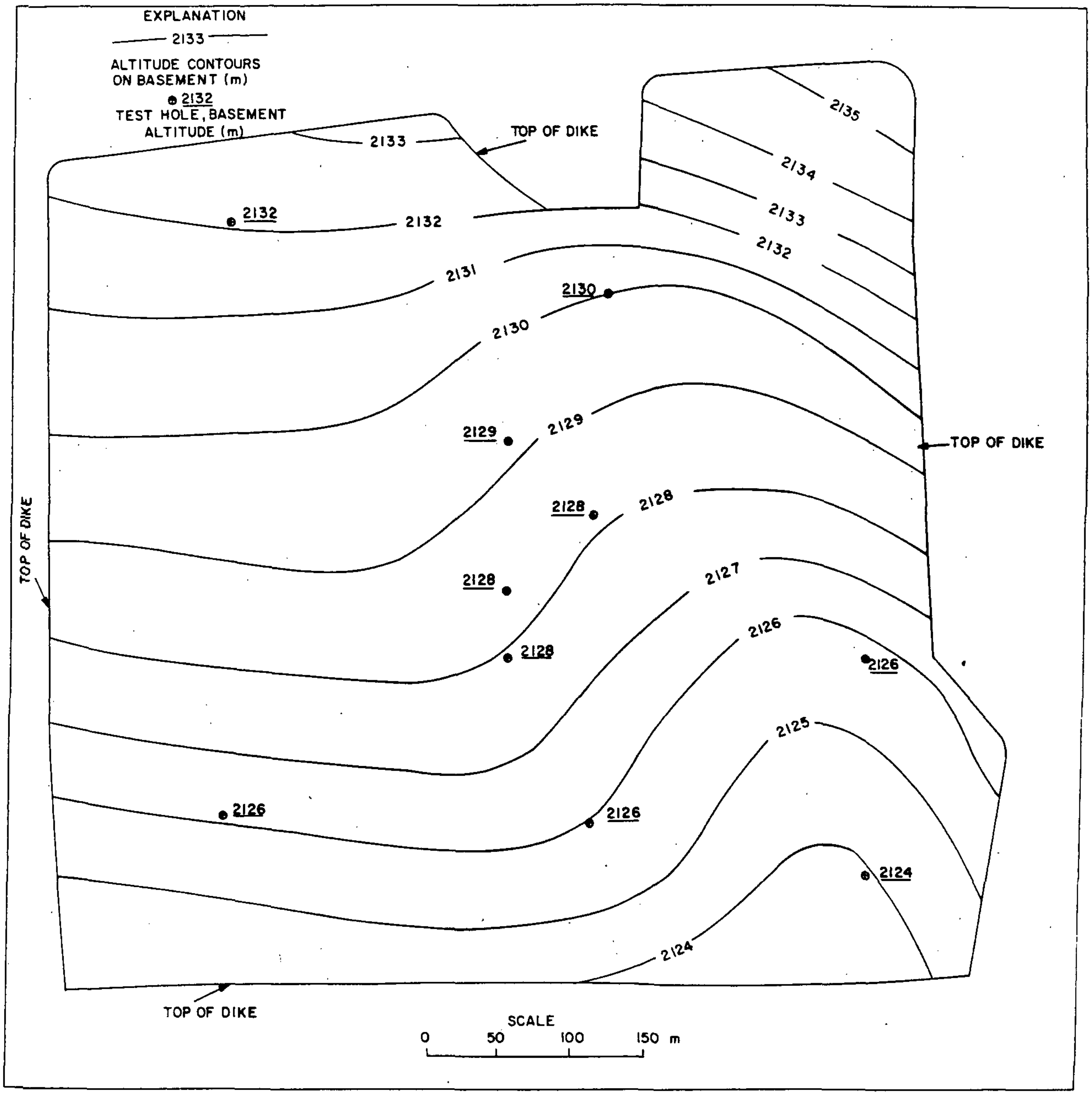


Fig. 8.
Topographic contours of original land surface beneath the tailings pile.

relative humidity, and a mean annual temperature of about 11°C, the average evaporation from shallow reservoirs is about 135 cm annually, or 5 times the annual precipitation (Table IV). The months of greatest evaporation loss include the months of greatest precipitation (June-September).

The ephemeral pond within the tailings basin was dry in July 1976. After rains in late July and August the pond began to fill. It had a surface area of about 40×10^3 m^2 on August 19. Precipitation (2.29 cm) on the evening of August 19 expanded the pond surface area by about 5×10^3 m^2 on August 20 (Fig. 10). The

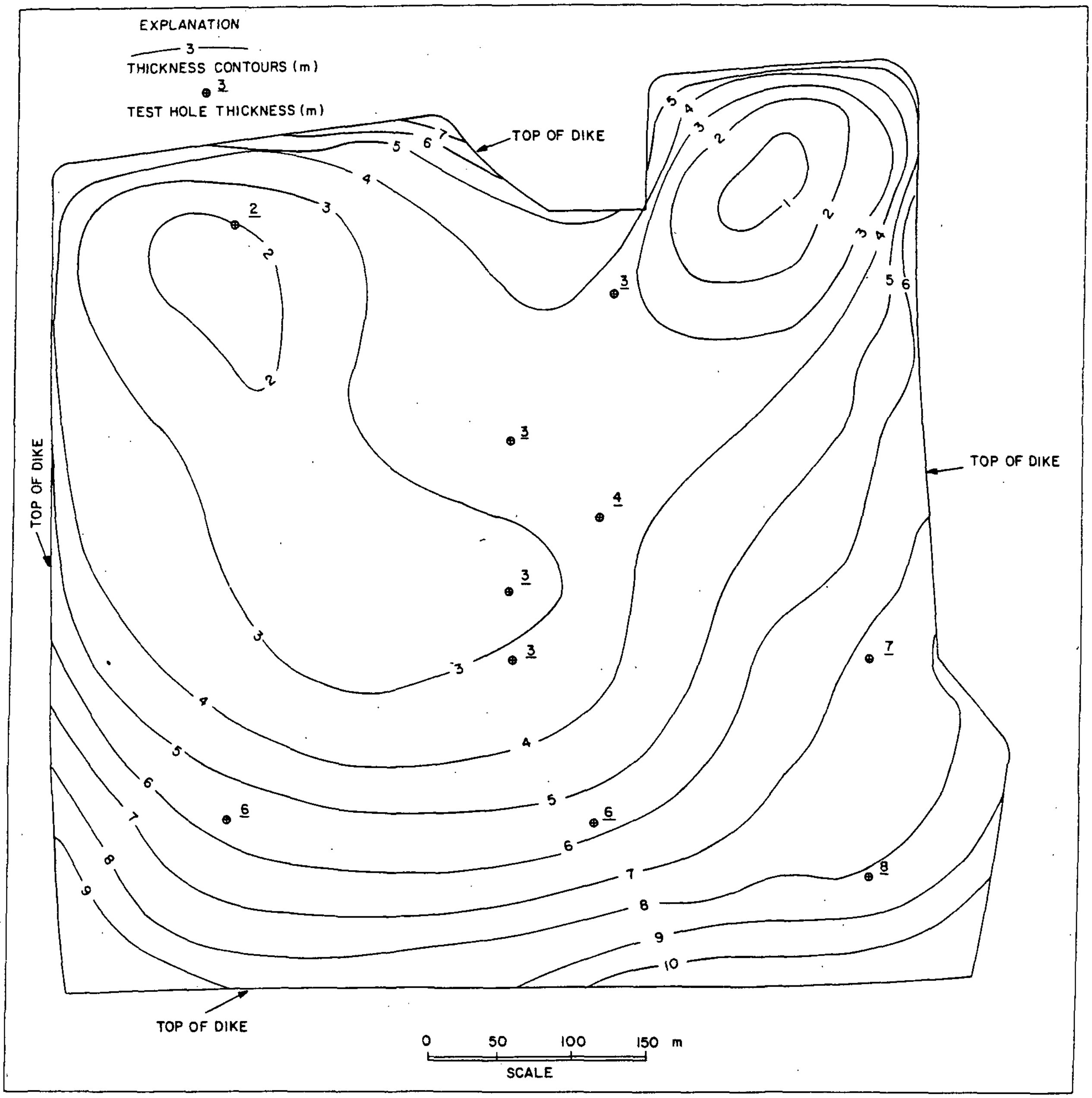


Fig. 9.
Isopach (thickness) map of the tailings.

inflow of water as the dike to the north was breached early on August 21 expanded the surface area to about 60 × 10^3 m^2 based on high water marks. The level of the pond declined 0.11 m from August 21 to September 14, or at a rate of 4.6 × 10^{-3} m/day. Measurements on September 13 and 14 indicated a decline of 5.0 × 10^{-3} m/day. These rates of decline are about the same magnitude as the average daily shallow reservoir evaporation, indicating little water loss from the pond into tailings.

There are three ponds adjacent to the mill tailings pile (Fig. 6). The largest (surface area ~8.4 × 10^3 m^2), located northeast of the pile, is used for storage of water pumped from a nearby mine and is used in mining operations. The depth of water in this pond is >1 m.

TABLE IV

MONTHLY SHALLOW RESERVOIR LOSSES DUE TO EVAPORATION

Month	Percent of Annual Evaporation	cm
January	1	1.4
February	1	1.4
March	5	6.7
April	9	12.1
May	14	18.9
June	17	22.9
July	16	21.6
August	14	18.9
September	12	16.2
October	6	8.1
November	3	4.1
December	2	2.7
	100	135.0

A smaller pond (surface area $\sim 3.2 \times 10^3$ m^2) lies north of the tailings pile. This pond is generally <1 m in depth. After a period of heavy rainfall (2.29 cm) on August 19, this pond was filled to within 8 cm of the top of the dike. The following evening heavy rain (1.08 cm) caused the pond to overflow, breaching the dike and allowing water to flow into the basin within the tailings pile. The breach in the dike caused by the inflow of water was about 5 m long and 0.7 m deep and cut down to an elevation of 2134 m. The volume of inflow was calculated as 9.5×10^3 m^3 from high water marks on the north side of the dike. The water cut a deep channel into the surface of the pile as the water drained into the basin. The volume of tailings cut from the channel was estimated at 560 m^3. These transported tailings built a fan out into the pond (Fig. 10).

The pond east of the tailings pile contains sewage effluent. The diked area of this pond is $\simeq 3.7 \times 10^3$ m^2, although the ponded area is only $\simeq 1.7 \times 10^3$ m^2.

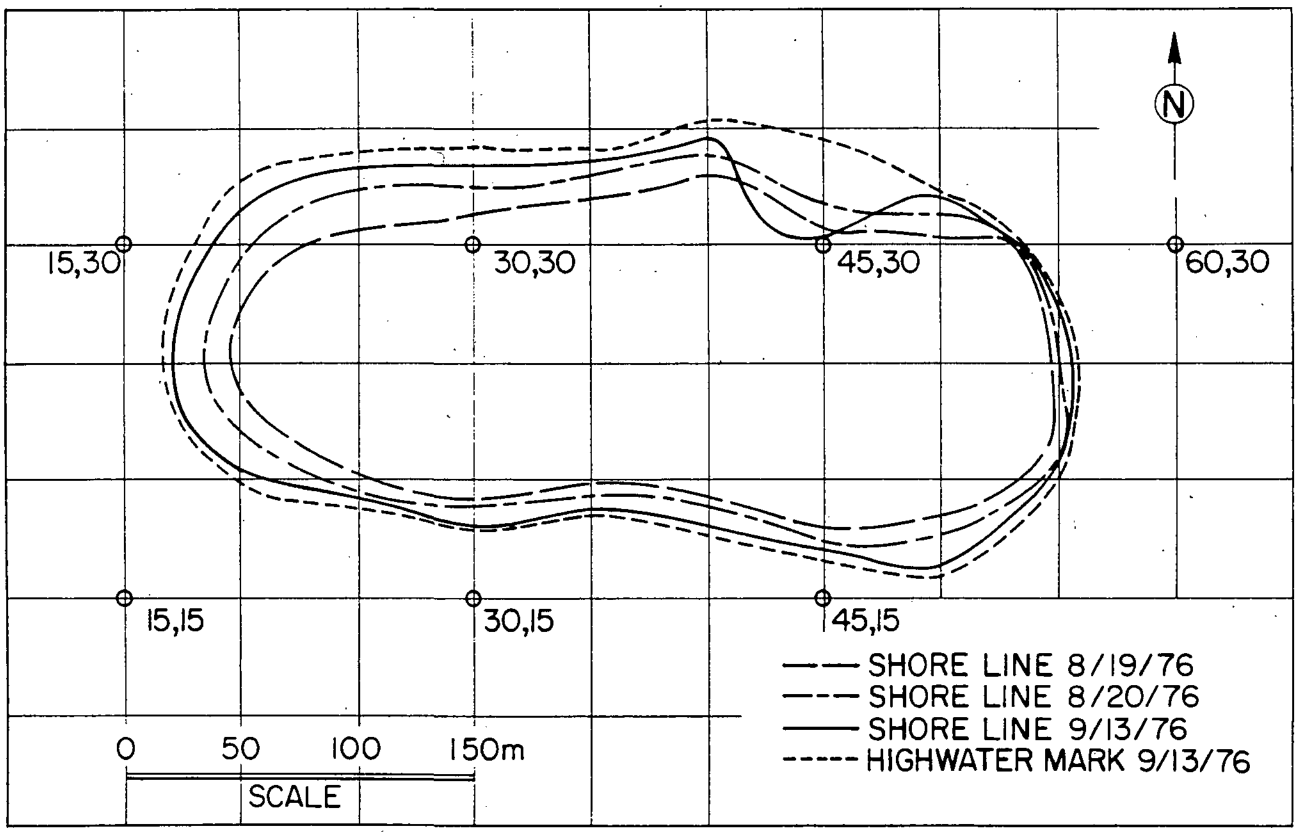


Fig. 10.
Map showing shore line as a result of precipitation, Aug-Sept 1976.

The depth of water in this pond is usually <1 m. Several other ponds are located east and northeast of the mill to catch runoff from part of the drainage (Fig. 6).

Other catchment areas worthy of mention are assessment pits north of the tailings pile and broad depressions that are located north of the pile and along the south edge of the pile between the toe of the dike and the road. There are approximately 100 assessment pits in the quarter-section north of the pile, ranging in size from 5.5 m long × 5 m wide × 0.75 m deep to 17 m long × 6 m wide × 2 m deep. The mean capacity of the assessment pits is 57 m^3. The potential retention of surface runoff is about 5.7 × 10^3 m^3 from the drainage to the north. The broad depressions north and south of the pile, when filled after heavy rains, have surface areas of approximately 20 × 10^3 m^2 and 50 × 10^3 m^2, respectively.

The drainage area above the tailings pile and including the mill is about 11 × 10^6 m^2. The altitude at the upper end of the drainage (Roman Hill) is about 2508 m and at the mill tailings pile is about 2130 m. Two well-defined channels carry runoff from Roman Hill. The eastern-most channel is about 2300 m long with a gradient of 0.03. Runoff in this channel is collected in three ponds east of the mill (Fig. 6). The channel to the west is about 3800 m long with a slightly steeper gradient of 0.09; however, as the channel emerges into the valley, the gradient decreases rapidly. About 1100 m north of the tailings pile the channel braids out and disappears into the area of numerous assessment pits.

The drainage from the north is allowed to pond on the north side of the pile. Subsequent drainage is around the pile on the western side where silty sandstone was removed to build the lower part of the dikes. Examination of the area indicates recent significant channel erosion in the shale near the northwest corner of the pile. There has been no erosion of the lower part of the dike by this channel.

The top of the dike is composed partly of sandy tailings that are subject to erosion by runoff which transports the tailings into the basin as well as down the outer edges of the dikes. The west dike is breached about 180 m north of the southwest corner and drains an area of approximately 3.5 × 10^3 m^2 on the pile. The south dike is breached about 90 m east of the southwest corner and drains an area of approximately 5 × 10^3 m^2 on the pile. Erosion has carried a significant amount of tailings into depressions on the south and west sides of the pile.

Meandering channels have cut into the surface of the pile carrying tailings into the basin. The channels on the north and western side of the basin are the most prominent. Most of these channels are less than 1 m deep and meanders are common. The meanders are characteristic of cutting on a relatively hard surface. The channels serve to collect a part of the fine-grained tailings transported by wind across the top of the pile. Runoff in these channels transports the fines into the basin, adding to the accumulation of slimes.

The surface of the pile is subject to wetting and drying cycles from intermittent precipitation. As precipitation infiltrates, it dissolves chemicals. During the drying cycle, the water in the tailings and chemicals are returned to the surface where the water evaporates and chemicals remain, leaving a hard crust.

The "spill point," or lowest edge of the dike as related to the pond in the basin, is the low area about 230 m north of the southwest corner. The elevation is about 2133 m (Appendix D). The estimated volume that the basin will hold is about 3 × 10^5 m^3, which would contain a surface area of about 1.9 × 10^5 m^2. If the total annual precipitation occurred in a day, it would have a volume of 9 × 10^4 m^3 (0.25 m × 3.7 × 10^5 m^2) over the area of the pile or fill the basin between the 2130 and 2131 contours (Fig. 7). However, runoff from the drainage north of the pile, entering the breach in the north dike, could cause this basin to overflow and in time would cause loss of pile integrity. The pond contains water in the late summer, during the winter, and in early spring and is dry during the late spring and early summer. The largest volume of water is lost to evaporation. Test holes in the eastern part of the pile indicate that a small volume infiltrates to the tailings and reaches a small body of water perched in the underlying formation.

The mill was active for 58 months, June 1958 to April 1963, during which time about 2.7 × 10^9 kg of tailings were discharged to form the pile. The amount of water released with the tailings is estimated at about 9.5 × 10^{-1} m^3 per 1 × 10^3 kg of tailings or about 2.6 × 10^6 m^3 of fluids.[23]

A water budget was prepared for the 58 months of operation to provide an estimate of loss of water from the milling operations into the underlying formations. The volume of water discharged into the pond during milling operations was estimated at 2.6 $\times 10^6$ m^3 (Table V). Annual precipitation to the pile was estimated at 25 cm over an area of 3.7 $\times 10^5$ m^3 (present area of pile), or about 46 $\times 10^4$ m^3 for the 58 months. The total volume of water to the pile (milling operation and precipitation) was 306 $\times 10^4$ m^3 (Table V).

Fluid remaining in the tailings pile was estimated at a moisture content of 36% of the 1.5 $\times$ 10^6 m^3 volume, or about 54 $\times$ 10^4 m^3 of water. Shallow reservoir evaporation was estimated at 656 cm for the 58-month period. The area of the pond used for the calculations was 1.8 $\times 10^5$ m^2 ($\simeq$0.5 the present area of pile). Thus the total evaporation was estimated at about 118 $\times$ 10^4 m^3. To complete the budget, the loss due to seepage was calculated at 134 $\times$ 10^4 m^3. Seepage loss was about 44% of the total fluids released into the pond.

The estimated daily seepage loss of 75 m^3 over an area of 1.8 $\times$ 10^5 m^2 would indicate a loss of fluids at about 4 $\times$ 10^{-4} m/day into the tailings and underlying formations.

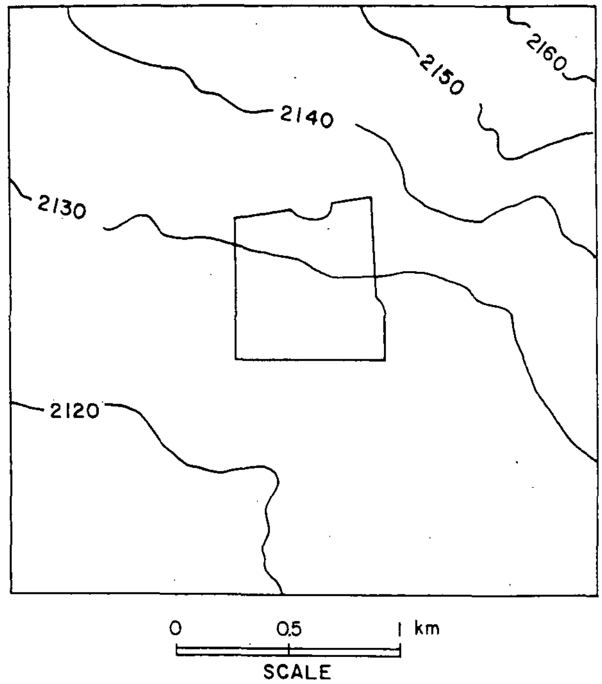


Fig. 11.
Topography adjacent to tailings pile.

C. Geology - Hydrology

The topography in the area slopes gently to the southwest at about 0.02 (Fig. 11). The area is underlain by shales and silty sandstones of the Mancos Shale. There is little if any alluvium overlying the Mancos Shale in the area adjacent to the pile. The upper thickness of the shale has been eroded off leaving only the lower units beneath the pile. Structural contours on the top of the Dakota Sandstone, i.e., base of the Mancos Shale, indicate that the beds dip at 0.03 to the northeast (Fig. 12). An isopach map shows the Mancos Shale thickening from about 100 m to 200 m, or at a rate of 0.05 to the northeast (Fig. 13).

Three silty sandstones within the lower part of the Mancos Shale have been mapped or logged as persistent in the area (Log V, Appendix A). The thicknesses ranged from 8.5 to 10.1 m interbedded with the shale (Fig. 13). The uppermost sandstone bed outcrops beneath roughly the western two-thirds of the tailings pile.

Seventeen test holes, ranging in depth from 3.8 to 14.3 m, were drilled around the edges of the tailings pile during July 1976. Seven other test holes and four well points were drilled or driven into the tailings pile. Logs, casing schedules, and other hydrologic data related to these test holes are presented in Appendix D. Hydrologic data were used to construct a map showing the water table and an approximate line of silty sandstone and shale contact (Fig. 14). For graphic representation of the water table see Appendix E.

TABLE V

WATER BUDGET
DURING MILL OPERATIONS
June 1958-April 1963

	m^3 $\times$ 10^4	
	To Pile	**Loss**
Fluids with tailings	260	---
Precipitation	46	---
Fluids remaining in pile	---	54
Evaporation	---	118
Seepage	---	134
	306	306

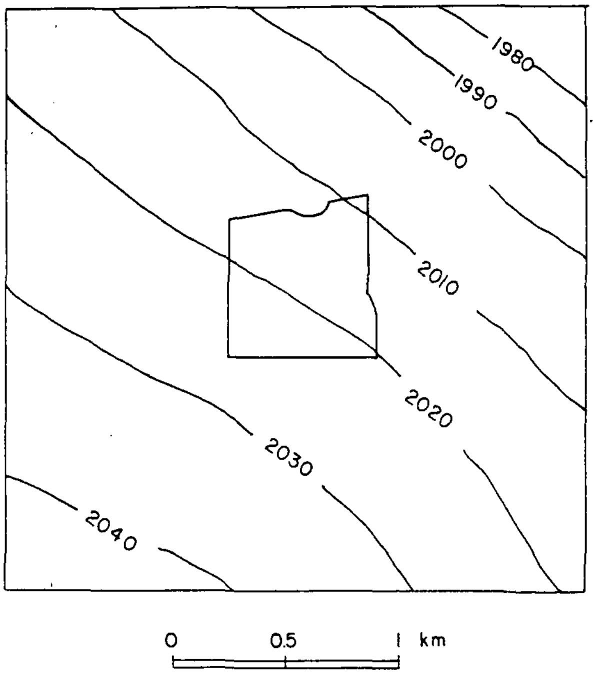


Fig. 12.
Structure contours on the top of Dakota Sandstone (base of Mancos Shale) in meters.

The water table beneath the pile slopes southwestward at depths of about 3.3 m at the northeast corner of the pile to about 10.3 m at the southwestern corner. The major influence or recharge to the shallow aquifer is from the ponds to the north and northeast of the pile. Summer runoff collecting along the north dike also adds to the recharge.

Water is within the shale member under roughly the eastern third of the pile and in the silty sandstone under the western two-thirds. There is probably some loss downdip into the sandstone to the northeast. The major movement of water is to the southwest, as shown by the contours.

Water in the tailings occurs in the southeast corner of the pile that coincides with the thicker section of tailings. This water is higher than the water table in the shale or sandstone and constitutes a mound of recharge to the lower aquifer. The water in the tailings is probably in part a residual of that discharged with the tailings and part infiltration of water from precipitation that collects in the basin within the tailings pile.

Two cased test holes located at the southeast and southwest corners adjacent to the pile were used as observation holes when the mill was active. These holes, 6.4 and 8.8 m below land surface, are now dry. There was probably a large loss of water from the pile during the operations of the mill that resulted in a higher water table in the shales and silty sandstones than now exists. Since operations have ceased, the water table has dropped.

Recharge in the area of the tailings pile to the water in shale and silty sandstone is mainly from the existing ponds and summer runoff. A minor amount of recharge occurs through the tailings from water collected in the basin within the pile.

D. Transport of Mill Tailings

The more obvious means of transport of mill tailings from the pile is by wind erosion and surface water. The prevailing winds appear to come from the southwest to northwest. Dunes caused by wind erosion of tailings have built up along the outer edge of the dike to the east.

Surface runoff is another means of tailings transport from the pile. Water erosion is evident on the outer face of the tailings dike. Further evidence for water erosion is indicated by the breaches through the tailings on the west and south and by the channels cut on the three access ramps. The breaches and access ramps drain an estimated total tailings pile area of 11.4×10^3 m^2. The basin within the dikes catches roughly 95% of the precipitation falling on the pile and is large enough to contain all of it except during the most severe storms. The other 5% runs off the pile via the three access roads and the two natural breaches.

The presence of ground water beneath and within the pile provides a possible transport mechanism for chemicals in the tailings pile. The water in the aquifer is recharged from nearby ponds. The movement of water in this aquifer is to the southwest with some loss into the sandstone units in the shale which would move to the northeast. The deeper aquifers at ~225 m in the sandstones would receive little or no recharge from the tailings pile.

The pile is located on the Ambrosia Lake ore trend. The ore within the aquifer in the Westwater Canyon Member was dewatered during mining.

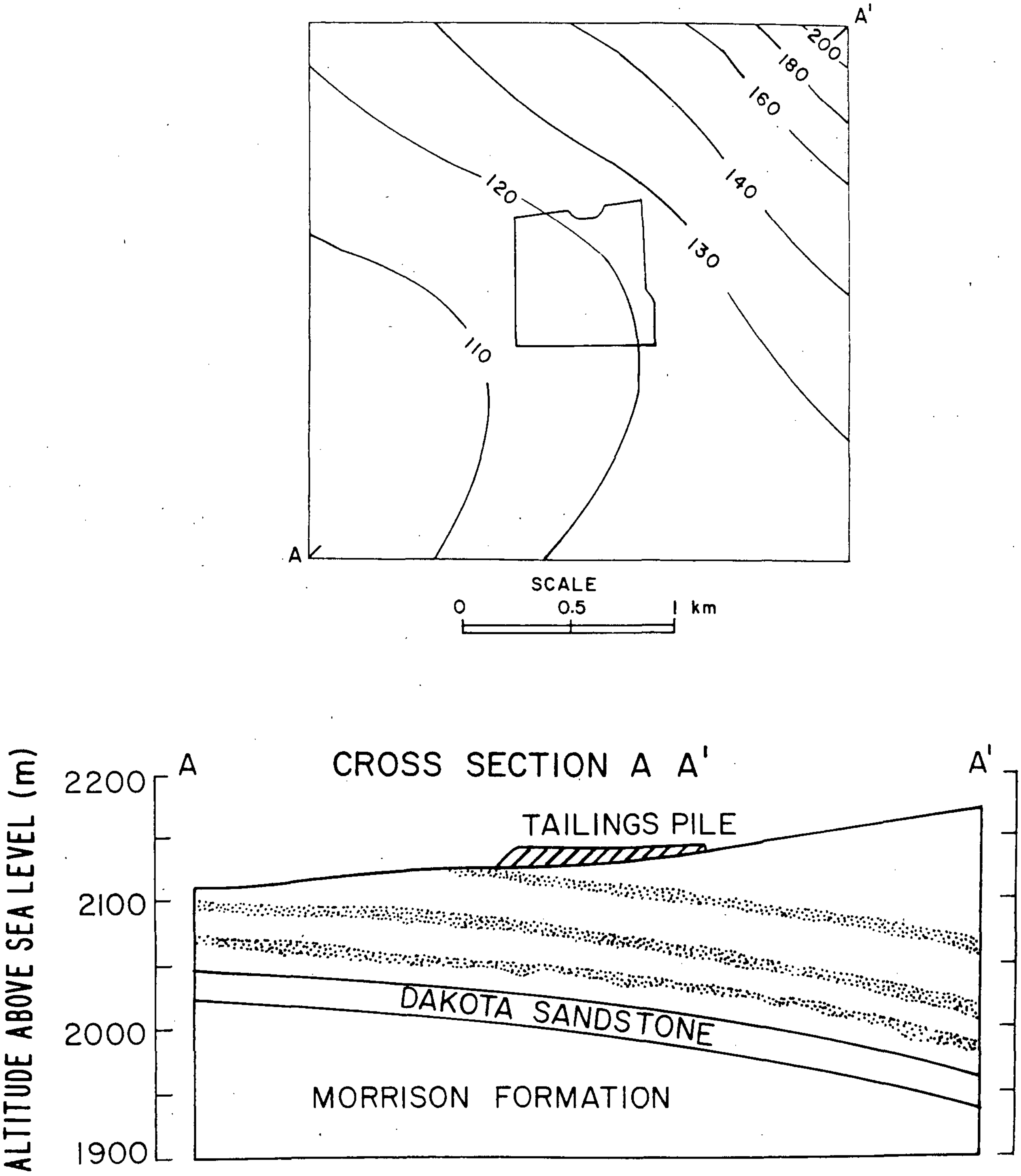


Fig. 13.
Isopach (thickness) map of the Mancos Shale in meters and cross section A-A' showing silty sandstone units in Mancos Shale.

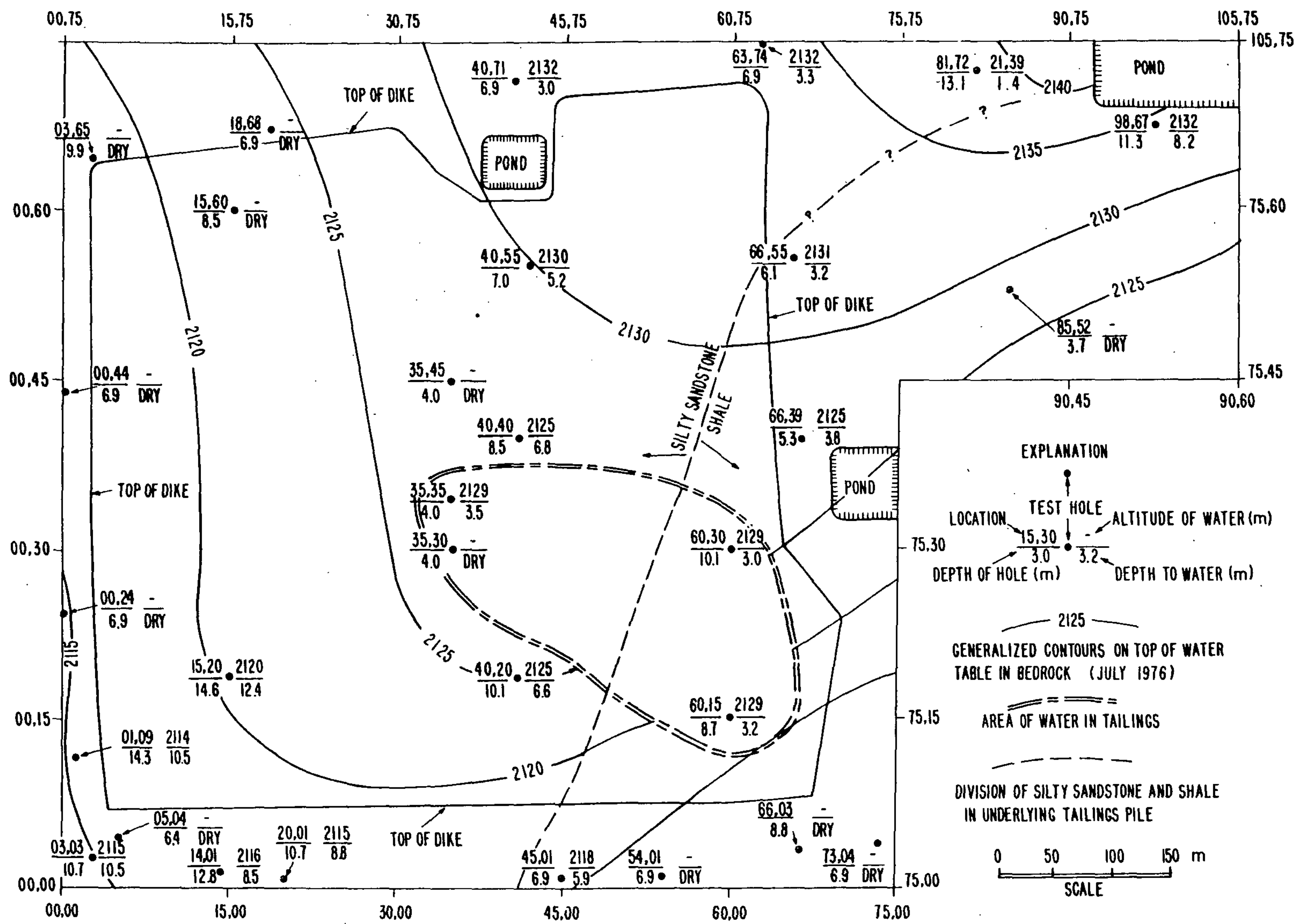


Fig. 14.

Hydrologic map of the tailings pile showing location of test holes, area of saturation in the tailings pile, and water level contours in the silty sandstones and shales of the Mancos Shale.

Water is still being pumped from the Westwater Canyon Member to be used in other mine-related activities. The removal of ore and water could cause subsidence in the area that would in time affect the stability of the pile.

There is no recognized folding or tilting of the formations underlying or adjacent to the tailings pile.[11] Fractures are common in the Westwater Canyon Member of the nearby mines; however, no fracture with major displacements greater than 2 to 5 cm was noted. These fractures were not persistent and extend only a few tens of meters. No faults were observed and it is thus surmised that surface rupture through faulting in the area is not likely.

The area of greatest seismic activity occurs along the Rio Grande Depression which constitutes the valley along the Rio Grande. This area is north-south trending and lies about 100 km to the west of the Ambrosia Lake area. In the most active seismic area of the depression, the largest shock in a 100-yr period is likely to be of magnitude 6 on the Richter scale.[24] The Ambrosia Lake area lies in the southern edge of the San Juan Basin. Here, the seismic activity is relatively low compared to that of the Rio Grande Depression. The seismic frequency is probably on the order of one shock of a magnitude of 4 or 5 in a 100-yr period. At a magnitude of 5, no damage would occur to this tailings pile. However, the shock could trigger subsidence due to the dewatering of mines and removal of ore that would affect the stability of the pile.

E. Radon Diffusion

Radon-222 (^{222}Rn) is a radioactive, inert gas, the direct result of the decay of ^{226}Ra, a radionuclide in the ^{238}U decay series (Table VI) and therefore present in uranium ores. Radon has a radioactive half-life of 3.8 days and decays to nongaseous radionuclides with half-lives ranging from 1.6×10^{-4} sec to 22 yr before stabilizing as ^{206}Pb. Although the half-life of ^{222}Rn is relatively short, its parent, ^{226}Ra, has a radioactive half-life to 1622 yr and is not excluded from the tailings during the milling process. Of the original ^{226}Ra concentration in the ores, 99.6-99.8% is discharged to the tailings pond in the sands and slimes from an acid-leach mill process, while 98-98.5% is similarly discharged from an alkaline mill process.[23] Radon deserves special attention relative to stabilization of uranium mill tailings piles because of the difficulties inherent in controlling a gas on such a large scale.

TABLE VI

PRINCIPAL EMISSIONS AND DECAY SEQUENCE OF THE URANIUM SERIES

Isotope	Half-Life	Radiation
^{238}U	4.5×10^{9} yr	α
^{234}Th	24.1 days	β
^{234}Pa	1.2 min	β
^{234}U	2.5×10^{5} yr	α
^{230}Th	7.5×10^{4} yr	α
^{226}Ra	1622 yr	α
^{222}Rn	3.8 days	α
^{218}Po	3.05 min	α
^{214}Pb	26.8 min	β
^{214}Bi	19.7 min	β
^{214}Po	1.64×10^{-4} sec	α
^{210}Pb	22 yr	β
^{210}Bi	5 days	β
^{210}Po	138.4 days	α
^{206}Pb	stable	---

Flux, or exhalation rate, of ^{222}Rn is defined as that amount which is transported across a unit area of a surface per unit time. This can be estimated for the Phillips pile. Using figures of 2.7×10^{9} kg of ore processed, an average ore content of 0.23% U_3O_8, and a relative ^{238}U abundance of 99.28%, it is calculated that there was a total of 5.3×10^{6} kg of ^{238}U present in the ore. Assuming secular equilibrium in the ore, it follows that there was a total of 1.9 kg of ^{226}Ra in that same ore. If 98% of the original ^{226}Ra content was discharged to the tailings, the Phillips Petroleum Company uranium mill tailings should contain an average of 677 pCi of ^{226}Ra per gram of tailings. Schiager[25] has predicted a radon flux for dry uranium mill tailings of 1.6 pCi ^{222}Rn per square meter per second for each picocurie of ^{226}Ra per gram of tailings. At 677 pCi ^{226}Ra per gram of tailings and assuming the same tailings parameters as Schiager, this would amount to a radon flux of 1083 pCi/m^2/s or 108 fCi/cm^2/s. Radon flux measurements are being conducted for the Phillips tailings pile using the accumulator method.[26] These are expected to vary considerably

TABLE VII

RADON FLUX FROM TAILINGS PILES

Tailings Pile	Condition	Flux fCi/cm²/s
Shiprock, New Mexico	uncovered	59
Shiprock, New Mexico	uncovered	132
Shiprock, New Mexico	uncovered	93
Salt Lake City, Utah	crusted, bare	15.1
Salt Lake City, Utah	crusted, bare	13
Salt Lake City, Utah	crusted, bare	15.8
Salt Lake City, Utah	crusted, bare	15.1
Salt Lake City, Utah	bare	65
Salt Lake City, Utah	bare	54
Salt Lake City, Utah	bare	78
Salt Lake City, Utah	bare	49
Salt Lake City, Utah	bare	24
Salt Lake City, Utah	bare	15.5

from this estimate due to the many variables including depth, porosity, and effective radium content of the tailings, attenuating influence of moisture in the tailings, and barometric pressure. Because of the differential settling of sands and slimes out of the tailings slurry, and because slimes contain from 77 to 94% of the total ^{226}Ra content of mill tailings,[18-19] the relative disposition of slimes in the tailings pile is a major determinant of radon flux. Radon flux measurements have been made at a few mill tailings piles (Table VII).[27]

IV. SUMMARY

The Phillips Petroleum Company tailings pile lies in the southern edge of the San Juan Basin. The area is underlain by a thick section of shales, siltstones, and sandstone. Aquifers capable of domestic or industrial water supply occur in the sandstones which make up less than 25% of the 1000 m thickness of sediments underlying the area. The sandstones dip gently into the basin; recharge to the aquifers occurs through their outcrops to the south. Several north-south trending faults occur in these sediments to the east of the pile. The quality of water in the sandstone aquifers is fair to poor with total dissolved solids ranging from 500 to over 2000 mg/ℓ.

The tailings pile forms a rough square about 620 m on a side containing a surface area of about 3.7×10^5 m². The tailings are contained within four dikes. The lower part of the dike is constructed from shales and silty sandstone excavated adjacent and beneath the present pile while the upper section is composed partially of tailings. The surface of the pile slopes inward to form a basin. The pile contains about 2.3×10^9 kg of tailings or a volume of about 1.5×10^6 m³. The thickness of the tailings ranges from <1 to 10 m.

Ground water perched in the silty sandstone and shales that underlie the pile are presently recharged from three ponds that are adjacent to the pile and from runoff north of the pile. Some water occurs in the tailings as a ground water mound indicating a small amount of recharge from the pond that forms in the basin from precipitation. The major movement of water in the perched aquifer in the shale and siltstone is toward the southwest. The deeper aquifer in the sandstone would receive little or no recharge from the tailings pile.

The most obvious transport of tailings is by wind erosion and surface water. Radon generated from the radium content of the pile is of possible consequence and is currently being studied.

ACKNOWLEDGMENTS

The authors take this opportunity to thank George Trujillo, J. Leo Martinez, and Ralph J. Alarid for their invaluable help with the field work upon which this report was dependent, and United Nuclear Corporation for cooperation, help, and information provided.

REFERENCES

1. Robert C. Merritt, *The Extractive Metallurgy of Uranium*, Colorado School of Mines Research Institute, USAEC Contract, Golden, Colo. (1971).

2. D. L. Barrs, "Permian Strata of Central New Mexico," in *New Mexico Geol. Soc. Guidebook, 12th Field Conf., The Albuquerque Country* (1961).

3. W. E. Cooley, "Triassic Stratigraphy in the State Line Region of West-Central New Mexico and East-Central Arizona," in *New Mexico Geol. Soc. Guidebook, 10th Field Conf., West-Central New Mexico* (1959).

4. J. B. Cooper and E. C. John, "Geology and Groundwater Occurrence in Southeastern McKinley County, New Mexico," N. Mex. State Engineers Tech. Rept. 35 (1968).

5. L. C. Craig, "Stratigraphy of the Morrison and Related Formations," U. S. Geol. Survey Bull. 1009-E (1955).

6. V. L. Freeman and L. S. Helpert, "Stratigraphy of the Morrison Formation in Part of Northwestern New Mexico," U. S. Geol. Survey Bull. 1030-J (1956).

7. E. D. Gordon, "Geology and Groundwater Resources of the Grants-Bluewater Area, Valencia County, New Mexico," N. Mex. State Engineer Tech. Rept. 20 (1961).

8. J. W. Harshbarger, C. A. Repenning and J. H. Irwin, "Stratigraphy of the Uppermost Triassic and Jurassic Rocks of the Navajo Country," U. S. Geol. Survey Prof. Paper 291 (1957).

9. C. B. Hunt, "Geology and Fuel Resources of the Southern Part of the San Juan Basin, and the Mount Taylor Coal Field," U. S. Geol. Survey Bull. 860-B (1936).

10. V. C. Kelley, "Regional Structure of the San Juan Basin," in *New Mexico Geol. Soc. Guidebook, 1st Field Conf., San Juan Basin, New Mexico and Colorado* (1950).

11. V. C. Kelley, compiler, "Geology and Technology of the Grants Uranium Region," N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Memoir 15 (1963).

12. J. D. Sears, C. B. Hunt and T. A. Hendricks, "Transgressive and Regressive Cretaceous Deposits in Southern San Juan Basin, New Mexico," U. S. Geol. Survey Prof. Paper 193-F (1941).

13. C. T. Smith, "Geology of the Thoreau Quadrangle, McKinley and Valencia Counties, New Mexico," N. Mex. Inst. Min. and Tech., State Bur. of Mines and Mineral Res., Bull. 31 (1954).

14. R. G. Young and G. K. Ealy, "Uranium Occurrence in the Ambrosia Lake Area, McKinley County, New Mexico," U. S. Atomic Energy Comm. Rept. RME-86 (1956).

15. R. T. Zitting, J. A. Master, S. A. Groth, and M. D. Webb, "Geology of the Ambrosia Lake Uranium Deposits, McKinley County, New Mexico," Mines Mag., **47** 3, 53-58 (1957).

16. John B. Squyres, "Geology and Ore Deposits of the Ann Lee Mine, Ambrosia Lake Area," in *Geology and Technology of the Grants Uranium Region*, V. C. Kelly, compiler, N. Mex. Inst. of Min. and Tech., State Bur. Mines and Mineral Res., Memoir 15 (1963).

17. "Report on Conditions of Uranium Millsite and Tailings at Ambrosia Lake, New Mexico," in *Phase 1 - Reports on Conditions of Inactive Uranium Millsites and Tailings in the Western United States*, U. S. Atomic Energy Commission, Grand Junction, CO (1974).

21. Personal communication, Ford, Bacon & Davis Utah, Inc., P. O. Box 8009, Salt Lake City, Utah 84108 (Sept 24, 1976).

18. R. M. Fry, "Radiation Hazards in Uranium Mining and Milling," Australian Atomic Energy Commission, AAEC/IP-9 (1975).

19. S. R. Borrowman and P. T. Brooks, "Radium Removal from Uranium Ores and Mill Tailings," Report of Investigations 8099, U. S. Bureau of Mines (1975).

20. "Environmental Analysis of the Uranium Fuel Cycle, Part 1 - Fuel Supply," U. S. Environmental Protection Agency, Office of Radiation Programs, Field Operations Division, Washington, DC, EPA-520/9-73-003-B (1973).

22. W. E. Hale, L. J. Reiland, J. P. Beverage, "Characteristics of the Water Supply in New Mexico," N. Mex. State Engineer, Tech. Rept. 31 (1965).

23. Don A. Clark, "State-of-the-Art. Uranium Mining, Milling, and Refining Industry," Robert S. Kerr, Environmental Research Laboratory, U. S. Environmental Protection Agency, EPA-660/2-74-038 (1974).

24. A. R. Sanford, A. J. Budding, J. P. Hoffman, O. S. Alptekin, C. A. Rush, and T. R. Toppozoda, "Seismicity of the Rio Grande Rift in New Mexico," N. Mex. Bur. Mines and Minerals Resources, Cir. 120 (1972).

25. Keith J. Schiager, "Analysis of Radiation Exposures on or Near Uranium Mill Tailings Piles," *Radiation Data and Reports* (July 1974).

26. M. H. Wilkening, W. E. Clements, and D. Stanley, "Radon-222 Flux from Widely Separated Regions," in *The Natural Radiation Environment II*, CONF-72 0805 P2, U. S. Energy Research and Development Administration (1975).

27. D. E. Bernhardt, F. B. Johns, and R. F. Kaufmann, "Radon Exhalation from Uranium Mill Tailings Piles, Description and Verification of the Measurement Method," Office of Radiation Programs - Las Vegas Facility, U. S. Environmental Protection Agency Technical Note, ORP/LV-75-7(A) (1975).

APPENDIX A

GEOLOGIC LOG OF REGIONAL WELLS AND TEST HOLES[a]

Log I	**KERMAC Water Well 1 SE 1/4 sec. 22, T14N, R10W Altitude 2138.5 m**	**Thickness (m)**	**Depth (m)**
Quarternary			
Alluvium		6.1	6.1
Cretaceous			
Mancos Shale		78.9	85
Dakota Sandstone		24.1	109.1
Jurassic			
Morrison Formation			
Brushy Basin Member		52.4	161.5
Westwater Canyon Member		59.5	221
Recapture Member		31.4	252.4
San Rafael Group			
Bluff Sandstone		30.4	282.8
Summerville Formation		99.4	382.2
Todilto Limestone		13.4	395.6
Entrada Sandstone		39.6	435.2
Triassic			
Chinle Formation(Undif)		454.2	889.4
Permian			
San Andres Limestone		33.5	922.9
Glorieta Sandstone		16.2	939.1

Log II	A. Berryhill Oil Test NE 1/4, sec 30, T14N, R9W Altitude 2130.6 m	Thickness (m)	Depth (m)
Quarternary			
Alluvium		18	18
Cretaceous			
Mancos Shale		79.8	97.8
Dakota Sandstone		20.5	118.3
Jurassic			
Morrison Formation			
Brushy Basin Member		38.1	156.4
Westwater Canyon Member		59.4	215.8
Recapture Member		44.8	260.6
San Rafael Group			
Bluff Sandstone		21.3	281.9

Log III	United Nuclear Water Well 1 SE 1/4 sec 28, T14N, R9W Altitude 2128.1 m	Thickness (m)	Depth (m)
Quarternary			
Alluvium		6.7	6.7
Cretaceous			
Mancos Shale		112.5	119.2
Dakota Sandstone		18.3	137.5
Jurassic			
Morrison Formation			
Brushy Basin Member		29.2	166.7
Westwater Canyon Member		57.9	224.6
Recapture Member		25.6	250.2
San Rafael Group			
Bluff Sandstone		86.9	337.1
Summerville Formation		102.1	439.2
Todilto Limestone		9.2	448.4
Entrada Sandstone		30.4	478.8
Triassic			
Wingate Sandstone		18.3	497.1
Chinle Formation (Undif)		443.2	940.3
Permian			
San Andres Limestone and Glorieta Sandstone (Undif)		57.9	998.2

Log IV	Sandstone Mine Test Hole SE 1/4, sec 34, T14N, R9W Altitude 2136.0 m	Thickness (m)	Depth (m)
Quarternary			
Alluvium		6.7	6.7
Cretaceous			
Mancos Shale		157.9	164.6
Dakota Sandstone		21.6	186.2
Jurassic			
Morrison Formation			
Brushy Basin Member		33.9	220.1
Westwater Canyon Member		57	277.1
Recapture Member		28.9	306

Log V	Cliffside Mine Test Hole SW 1/4, sec 36, T14N, R9W Altitude 2154.9 m	Thickness (m)	Depth (m)
Quarternary			
Alluvium		33.5	33.5
Cretaceous			
Mancos Shale			
Shale		27.7	61.2
Sandstone		5.2	66.4
Shale		186.5	252.9
Sandstone		8.5	261.4
Shale		28	289.4
Sandstone		9.1	298.5
Shale		19.2	317.7
Sandstone		10.1	327.8
Shale		15.2	343
Dakota Sandstone		19.1	362.1
Jurassic			
Brushy Basin Member		50.9	413
Westwater Canyon Member		44.2	457.2

[a]From Cooper and John, Ref. 4

APPENDIX B

QUALITY OF WATER FROM MINES AND A NETWORK ADJACENT TO THE KERMAC MILL*

The U. S. Environmental Protection Agency conducted an environmental survey of the Ambrosia Lake area during February and March 1975. During this investigation, samples of mine water pumped into the ponds were collected and analyzed. The locations of the ponds are shown in Fig. B-1, while the results of the trace element analyses are shown in Table B-I.

Samples were collected and analyzed from monitoring stations adjacent to the KERMAC Mill and mill tailings pond during the survey. The locations of monitoring stations are shown in Fig. B-2, while results of analyses and depth of observation holes are shown in Table B-II.

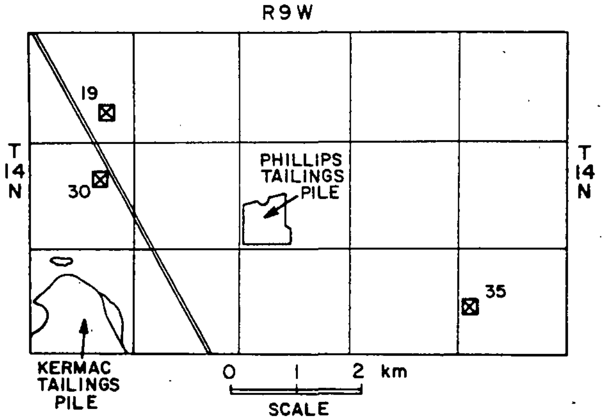


Fig. B-1.
Location of mine water sampling stations.

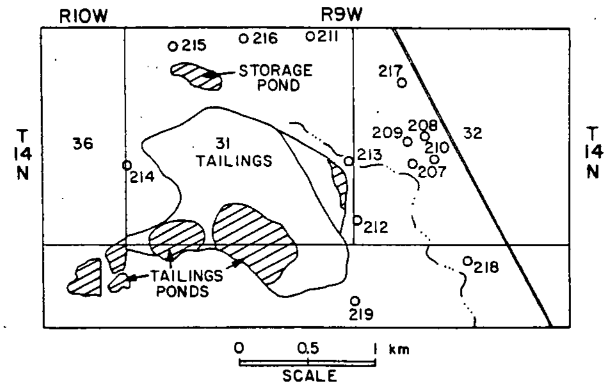


Fig. B-2.
Location of observation wells and seep adjacent to KERMAC mill.

*U. S. Environmental Protection Agency, Region VI, Dallas, Texas, "Water Quality Impacts of Uranium Mining and Milling Activities in the Grants Mineral Belt, New Mexico," EPA 906/9-75-002 (1975).

TABLE B-I

CHEMICAL QUALITY OF MINE WATER[a]

Location[b]	Date 1975	mg/ℓ[c] Mo	Na	Se	V	Mn	Cl	NH_3	NO_2 + NO_3	TSS	Total Uranium	pCi/ℓ[d] Dissolved Gross Alpha	Dissolved ^{226}Ra
KERMAC Sec 30W	2-26	2.8	160	0.03	0.8	0.15	---	0.19	1.3	---	1.3	1300	174
Do.	2-27	2.6	160	0.04	0.7	0.18	52	0.21	1.2	26	6.1	1400	161
Do.	2-28	2.6	160	0.03	0.7	0.17	49	0.18	0.94	23	6.7	1400	154
Do.	3-1	---	---	---	---	---	53	---	---	17	---	---	---
KERMAC Sec 19	2-27	0.6	120	<0.01	0.6	0.03	7.9	0.13	1.4	16	0.23	72	9.3
KERMAC Sec 35	2-26	5.2	190	0.08	0.6	0.09	---	0.11	0.22		17	3000	32
Do.	2-27	5.0	200	0.08	0.7	0.04	9.4	0.15	0.39	120	14	2400	52
Do.	2-28	4.7	210	0.04	1.0	0.06	7.6	0.06	0.44	93	26	2800	69
Do.	2-31	---	---	---	---	---	8.4	---	---	86	---	---	---

[a]See footnote, p. 27.
[b]See Figure B-1 for location.
[c]Samples unfiltered.
[d]Samples filtered.

TABLE B-II

MONITORING ADJACENT TO KERMAC MILL[a]

			mg/ℓ						pCi/ℓ	
Location[b]	1975	Well Depth (m)	Se	V	Cl	NH_3	NO_2 + NO_3	TDS	Gross Alpha	^{226}Ra
207	2-27	12.5	<0.01	0.4	3100	0.50	0.04	14 000	410	1.1
208	2-27	16.2	0.29	0.8	4	---	---	7800	49	4.0
209	2-27	42.1	0.01	<0.3	17	0.66	48.7	2700	<2	2.0
210	2-27	19.2	---	---	44	0.30	350	6300	45	0.26
211	2-27	16.2	<0.1	0.5	31	0.80	1.3	4100	<3	0.20
212	3-3	c	---	---	3100	590	53	36 000	112 000	4.9
213	3-3	8.2	<0.1	0.6	3400	0.12	0.25	8900	8	6.6
214	3-3	17.4	0.02	<0.3	1700	2.9	8.0	9100	14	1.2
215	3-3	11.6	<0.01	<0.3	100	10.0	2.0	3200	104	2.5
216	3-3	18.9	---	---	74	0.80	2.6	2600	45	0.64
217	3-3	16.6	---	---	470	9.1	70.9	4700	70	0.94
218	3-3	10.4	---	---	61	0.16	0.40	4800	20	0.34
219	3-3	10.4	0.01	<0.3	1300	0.08	1.3	6700	67	0.59

[a]See footnote, p. 27.
[b]See Figure B-2 for location.
[c]Seepage return.

NOTE: Location No. 207 to 211 and 213 to 219 the ^{230}Th ranged from <0.013 to 0.27 pCi/ℓ, ^{232}Th ranged from <0.011 to 0.27 pCi/ℓ, and ^{210}Po ranged from <0.03 to 3.8 pCi/ℓ.

APPENDIX C

PHILLIPS URANIUM MILL TAILINGS PILE LOCATION AND SURVEY (UNITED NUCLEAR CORP.)

An engineering survey was made in May 1976 by ENG-1 of the Los Alamos Scientific Laboratory of the tailings pile and adjacent area (Fig. C-1).

The engineering survey laid out a 750 m × 750 m square with grid points at 150-m intervals. Later, intermediate points were placed at 50-m intervals throughout the whole grid.

The southwest corner of the grid, Fig. C-1, was denoted by the coordinates 00,00. The point 45,60, for example, is 450 m east of 00,00 and 600 m north of 00,00.

Steel fence posts 2 m long mark the 150-m points, while 1-m aluminum stakes mark the 50-m grid points.

APPENDIX D

GEOLOGIC LOGS, HYDROLOGIC DATA, AND WELL CONSTRUCTION OF TEST HOLES JULY 1976

Test holes were drilled and cased on, and adjacent to, the tailings pile during the week of July 12-16, 1976. The holes were drilled to collect geologic and hydrologic information. Samples of cuttings were collected for chemical and radiochemical analyses (as part of the continuing study). Holes containing water were cased to facilitate water sampling and analyses (as part of the continuing study). Additional hydrologic data are to be collected to determine water-level trends and seasonal variations.

Nineteen test holes were drilled adjacent to the pile. The location of the wells is denoted by the coordinate points nearest the wells, as shown on Fig. 14. For a description of coordinate system, see Appendix C. The geologic logs are given in Table D-I. Soil or alluvium was generally less than 0.5 m thick. The hole at locations 00,24 and 66,39 contained up to 1 m of tailings that were deposited by water erosion and wind erosion, respectively.

Seven test holes were drilled through the pile (Fig. 14). The log of the holes is presented in Table D-II. The holes near the edges of the dikes penetrated tailings which were mainly fine sands with lenses of slimes. The holes in the basin penetrated mainly slimes with lenses of fine sand. The logs show the thickness of tailings and bedrock (shale or silty sandstone) penetrated.

Three well points (3.2-cm steel pipe with a well point) were driven through the tailings into the bedrock. Logs are shown in Table D-I. The bedrock was determined by change in penetration rate. The hole at location 60,15 was completed as an observation well with a drive point.

Well construction and hydrologic data are shown in Table D-III. The holes were drilled using a truck-mounted power auger. All holes were drilled 10.2 cm in diameter, with the exception of the hole at location 01,09 which has a diameter of 7.6 cm. The holes containing water were cased with 5.1-cm-diam plastic pipe perforated in the lower 1.8 m. The perforations were wrapped with stainless steel screen. Surface casing, generally about 1 m in length, was placed in holes that were dry.

Observation wells at locations 15,20 and 15,60 were cased to various depth intervals in the tailings to conduct radon studies.

Observation wells at locations 05,04 and 66,03 contain steel casing. The wells were installed prior to July 1976, probably when the mill was in operation, for monitoring purposes. The hole at location 98,67 is a 12.7-cm uncased exploratory core hole adjacent to the mine water holding pond. It was drilled as part of the exploratory test to outline the ore body in the Westwater Canyon Member. These types of holes were drilled on 30- to 50-m centers in the area. A number of these core holes were located; however, only three near the pond were open. The remainder were either plugged up on completion of the exploratory drilling phase or sealed by the swelling of shales and clays.

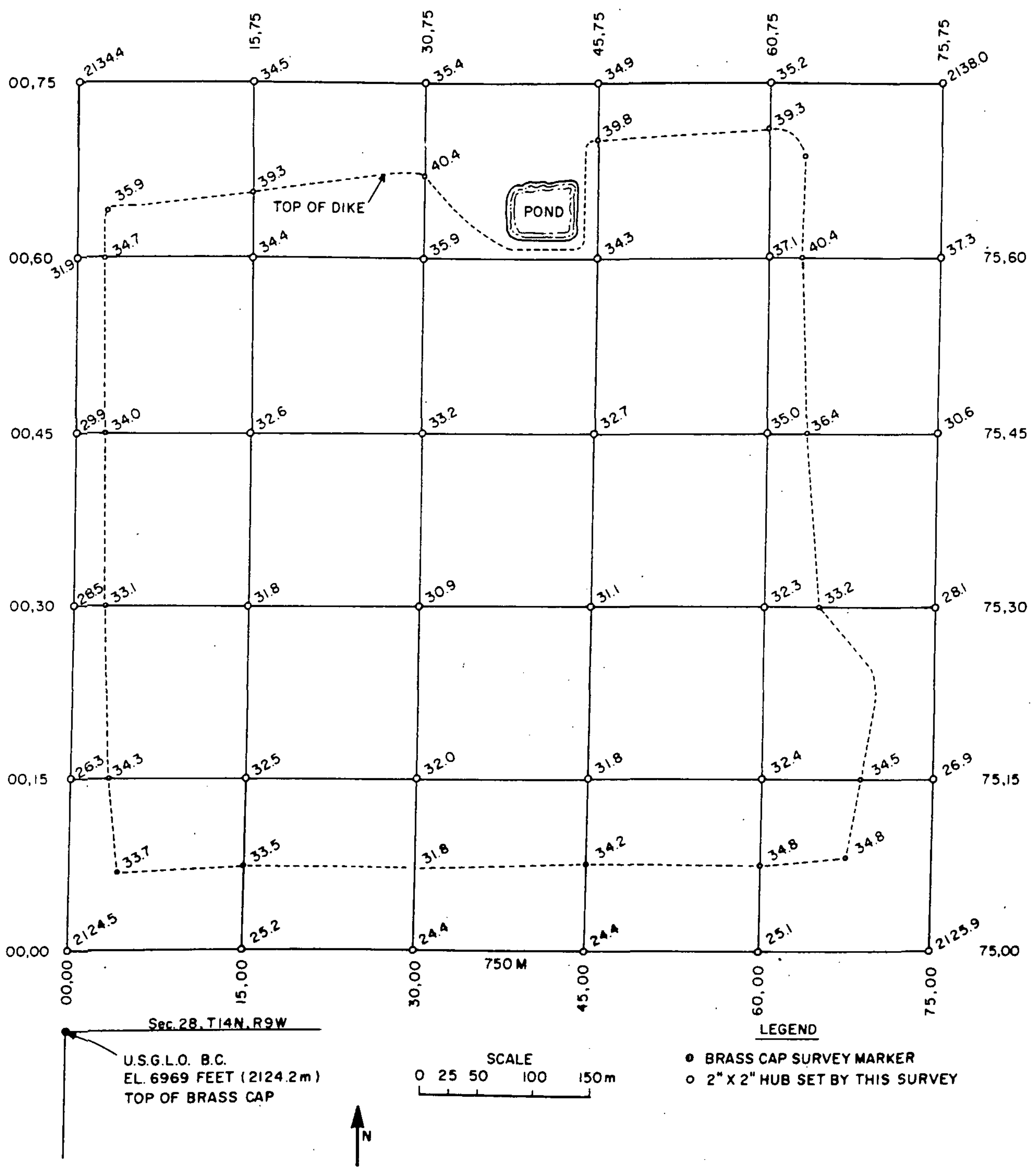


Fig. C-1.
Phillips Petroleum Company mill tailings pile location and survey (grid point elevation in meters).

TABLE D-I

LOGS OF TEST HOLES ADJACENT TO TAILINGS PILE

Location	Description	Thickness (m)	Depth (m)
03,03	Silty sandstone, light brown	6.7	6.7
	Shale with lenses of silty sandstone, light brown	4	10.7
14,01	Silty sandstone, light brown	11.3	11.3
	Shale, gray	1.5	12.8
20,01	Silty sandstone, light brown	10.7	10.7
45,01	Shale, light brown	6.9	6.9
54,01	Shale, light brown	3.1	3.1
	Silty sandstone, light brown with lenses of shale	1.5	4.6
	Shale, light brown	2.3	6.9
73,04	Silty sandstone, light brown	3.7	3.7
	Shale, light brown	3.2	6.9
00,24	Tailings, gray, light gray (outwash)	1.2	1.2
	Silty sandstone, light brown	4.9	6.1
	Shale, light brown	0.8	6.9
00,44	Silty sandstone, light brown	6.9	6.9
66,39	Tailings, light gray (outwash)	0.9	0.9
	Shale, light brown	4.4	5.3
66,55	Shale, light brown	4.9	4.9
	Shale, dark gray	1.2	6.1
03,65	Silty sandstone, light brown	6.1	6.1
	Shale, light brown	2.1	8.2
	Shale with lenses of silty sandstone, light brown	1.5	9.8
18,68	Silty sandstone, light brown	3.1	3.1
	Shale, light brown	1.5	4.6
	Shale, gray with lenses of silty sandstone	2.3	6.9
40,71	Silty sandstone, light brown	2.4	2.4
	Shale with lenses of silty sandstone, light brown	4.5	6.9
63,74	Silty sandstone, light brown	6.9	6.9
01,09	Silty sandstone, light brown	14.3	14.3

TABLE D-II

LOGS OF TEST HOLES ON TAILINGS PILE

Location	Description	Thickness (m)	Depth (m)	Location	Description	Thickness (m)	Depth (m)
15,20	Tailings	6.1	6.1	15,60	Tailings	2.4	2.4
	Bedrock	7	13.1		Bedrock	6.1	8.5
40,20	Tailings	6.1	6.1	40,55	Tailings	2.7	2.7
	Bedrock	4	10.1		Bedrock	4.3	7
60,15	Tailings	7.6	7.6	35,30	Tailings (Well Point)	3.1	3.1
	Bedrock	0.9	8.5		Bedrock	0.3	3.4
60,30	Tailings	7	7	35,35	Tailings (Well Point)	3.1	3.1
	Bedrock	3.1	10.1		Bedrock		
40,40	Tailings	3.7	3.7	35,45	Tailings (Well Point)	2.7	2.7
	Bedrock	4.9	8.6		Bedrock	1.5	4.2

TABLE D-III

TEST HOLE CONSTRUCTION AND HYDROLOGIC DATA

Location X	Location Y	LSD	Depth	Length of Casing	MP Above LSD	7-16-76 LSD Water Level	7-16-76 Water Altitude	8-16-76 LSD Water Level	8-16-76 Water Altitude	9-14-76 LSD Water Level	9-14-76 Water Altitude
ADJACENT TO PILE:											
03	03	2125	10.7	0.9	0.3	10.5	2114	10.3	2115	10.4	2115
01	09	25	14.3	12.5	0.6	10.5	2114	10.0	2115	10.0	2115
00	24	28	6.9	0.9	0.3	a		a		b	b
00	44	30	6.9	0.9	0.3	a		a		a	
03	65	32	9.9	0.9	0.3	a		a		a	
05	04	25	6.4	6.4	0.	a		b	b	a	
14	01	24	12.8	13.1	0.6	8.5	2116	9.2	2115	10.0	2114
20	01	24	10.7	11.3	0.6	8.8	2115	6.9	2117	6.0	2118
20	01 A	24	5.3	0.6	0.3	a		a		b	b
18	68	34	6.9	0.9	0.3	a		a		b	b
40	71	35	6.9	6.7	0.6	3.0	2132	2.3	2133	1.7	2133
40	71 A	35	3.8	0.9	0.3	a		2.0	2133	c	c
45	01	24	6.9	7.3	0.6	5.9	2118	b	b	5.8	2118
54	01	25	6.9	0.9	0.3	a		a		b	b
66	03	25	8.8	9.9	1.1	a		a		a	
66	39	29	5.3	5.8	0.6	3.8	2125	2.4	2127	2.1	2127
66	55	34	6.1	0.9	0.3	3.2	2131	2.6	2131	b	b
63	74	35	6.9	6.7	0.6	3.3	2132	3.2	2132	3.0	2132
73	04	26	6.9	0.9	0.3	a		a		b	b
81	72	40	13.1	7.7	0.6	1.4	2139	0.5	2140	1.0	2139
85	52	32	3.7	0.9	0.3	a		a		a	
98	67	40	11.3	none	0	8.2	2132	4.5	2136	3.8	2136
ON PILE:											
15	20	32	14.6	1.8	0.6	12.4	2120	12.4	2120	b	b
15	60	34	8.5	2.4	0.3	a		a		b	b
35	30 [1]	31	4.0	4.8	0.8	a		b	b	b	b
35	35 [1]	32	4.0	4.8	0.8	3.5	2128	3.8	2128	3.9	2128
35	45 [1]	33	4.0	4.8	0.8	a		a		a	
40	20	32	10.1	8.5	0.6	6.6	2125	6.7	2125	b	b
40	40	32	8.5	7.3	0.6	6.8	2125	6.7	2125	6.7	2125
40	40 A	32	3.0	0.6	0.3	a		a		b	b
40	55	33	7.0	5.2	0.9	5.2	2128	4.7	2128	4.4	2129
60	15 [1]	32	8.7	9.6	0.9	3.2	2129	3.3	2129	3.3	2129
60	30	32	10.1	5.2	0.9	3.0	2129	3.0	2129	3.0	2129

[1] Well Point

[a] Dry
[b] No data
[c] Caved in

APPENDIX E

COMPUTER GRAPHICS OF SELECT PARAMETERS

The topography on top of the tailings pile, original land surface, and water level in the area have been plotted using computer graphics to supplement Figs. 8, 9, and 14 in the text. These are shown in Figs. E-1, E-2, and E-3, respectively, for graphic comparison. The computer routine takes the altitude data (Z-axis) and interpolates the altitude contours by weighing the data.

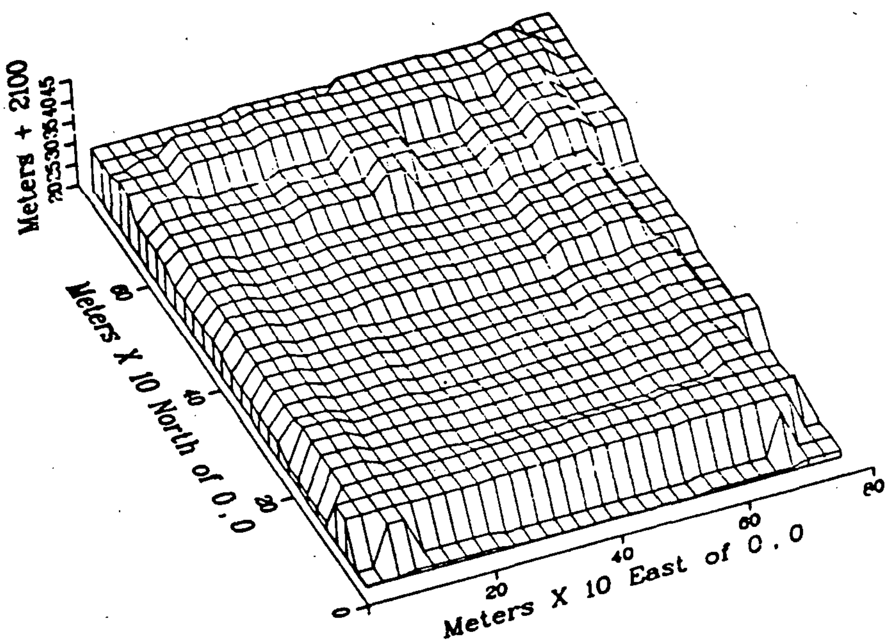


Fig. E-1.
Topography on and adjacent to tailings pile (based on altitude of survey points, Fig. C-1).

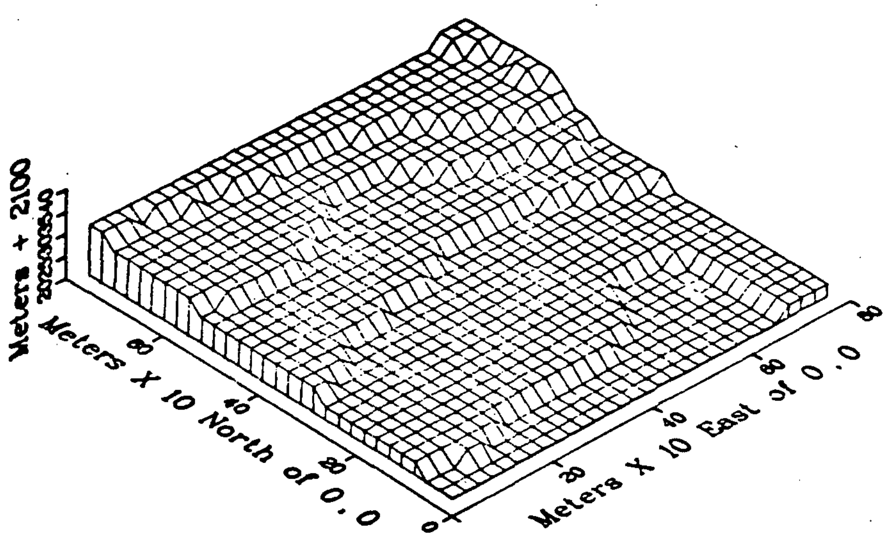


Fig. E-2.
Topography of land surface under and adjacent to tailings pile.

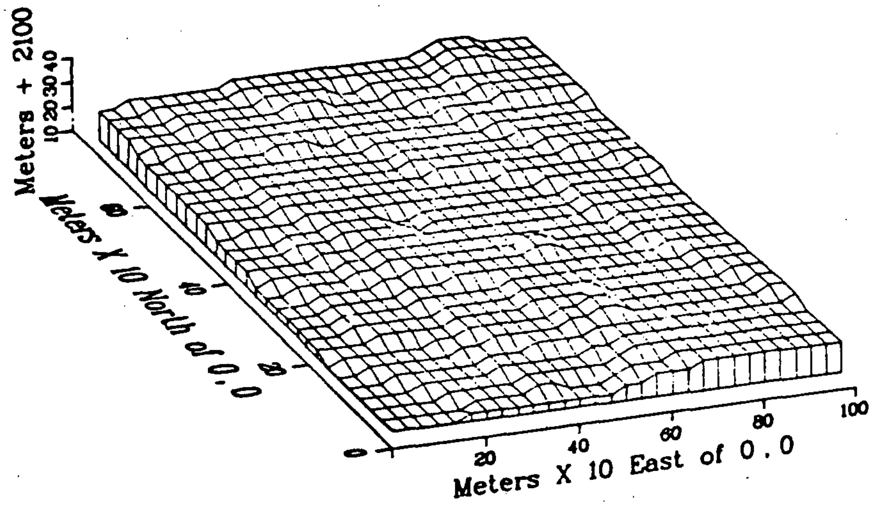


Fig. E-3.
Altitude of water levels in and adjacent to tailings pile (average July, August, and September 1976).

☆ U.S. GOVERNMENT PRINTING OFFICE 1977—777-018/77

Doug Jones

24

HYDROGEOLOGY AND WATER RESOURCES

OF THE

AMBROSIA LAKE-SAN MATEO AREA

McKINLEY AND VALENCIA COUNTIES, NEW MEXICO

HEALTH

& ENVIRONMENT

department

HYDROGEOLOGY AND WATER RESOURCES OF THE AMBROSIA LAKE-SAN MATEO AREA McKINLEY AND VALENCIA COUNTIES, NEW MEXICO

by

Robert C. Brod

RECEIVED
JUL 20 1981
EID: WATER POLLUTION CONTROL

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Science in Geology

New Mexico Institute of Mining and Technology

Socorro, New Mexico

June, 1979

CONTENTS

LIST OF FIGURES

A large amount of artificial recharge results from the discharge of mine wastewater near the town of Ambrosia Lake. Kaufmann and others (1975) indicated that the seepage from tailings ponds equalled 0.36 mgd (1.36 X 10^6 l/day) in 1974. The Arroyo del Puerto, which runs south from the Ambrosia Lake area to San Mateo Creek, has been perennial since large amounts of mine wastewater began to be discharged into it in the late 1950's. In fact, grasses and cattails now grow along its banks. In Figure 25 water levels in the alluvium show a gradient perpendicular to the channel direction, indicating recharge along the arroyo. A well, believed to be completed in the Mancos Shale, contains water with noticably fewer dissolved solids (27 mg/l) than the surrounding alluvial wells. This suggests that although the ion-rich discharge water recharges the alluvium it probably does not penetrate the Mancos Shale. The underlying sandstone aquifers may, however, receive some of the recharge in places where they lie directly under the alluvium.

Such a situation seems to exist at the confluence of the Arroyo del Puerto and San Mateo Creek. At that point the Dakota has been dissected by the creek. Well depths and the geologic map suggest that near the confluence nearly 100 feet (30 m) of alluvium lie directly on the Morrison Formation. Kauffmann and others (1975) have shown that the discharge from the Arroyo del Puerto has nearly doubled the TDS concentration in the alluvial ground water below the confluence. As cited in the section of this report on ground-water chemistry, the TDS concentration of the Morrison

GROUND-WATER FLOW SYSTEM

Recharge

Precipitation is the original source of recharge, and the average annual precipitation in the study area ranges from about 12 inches (30 cm) per year in the lower areas to nearly 20 inches (51 cm) on Mt. Taylor (Tuan and others, 1969). Most of the sandstone outcrops in the area form cliffs, and offer little area for direct recharge from precipitation. An exception to this is the Dakota Sandstone cap on Mesa Montañosa and the western end of La Jara Mesa, where the exposure is commonly more than a mile wide. The Point Lookout Sandstone cap on San Mateo Mesa is also extensive, but is highly dissected and probably not significantly connected to those places in the study area where the formation lies under the surface.

It may be assumed that little precipitation enters the bedrock outcrops through their primary porosity, for the permeability is generally so low that water is evaporated back out soon after it infiltrates. The runoff on outcrops, though, may cross fractures, and it is probably through the fractures that most recharge occurs. In a study of recharge through exposed, fractured limestone in southern New Mexico, Paul Davis (hydrologist, U.S. Geological Survey, Albuquerque, personal communication) calculated that 20 to 25 percent of the annual precipitation recharged the bedrock aquifer. It may be assumed that the limestone had no primary permeability. In a sandstone outcrop, however, some of the precipitation would enter ther primary pores, but would probably be lost to evaporation soon afterwards. It is estimated that approximately 15 to 20 percent of the precipitation enters the broad Dakota outcrop as recharge.

From geologic maps it has been estimated by the author that approximately 10 square miles (26 km^2) of Dakota outcrop lie up-dip from the study area. Assuming an annual precipitation rate of 13 in. (33 cm) and a recharge rate of 17 percent, it is estimated that about 0.11 mgd/sq. mi. (million gallons per day per square mile; 4.2×10^5 $l/d/km^2$) are recharged through the Dakota outcrop. Although much of this water probably remains in the unit, a great deal probably enters the underlying formations through the ubiquitous fractures in the outcrop area.

Figure 21 shows the grain-size distributions for three alluvium samples taken in the area. Two samples from gentle slopes consist of fine sand with 5 to 10 percent silt and clay, and are believed to be of eolian origin. According to local soil maps, most of the soils in the area have an infiltration rate of less than 2 in. (5 cm) per hour. At this rate, and because of the sealing effects of clay and raindrop impact, it may be expected that rainfall penetrates only a small distance into the soil, only to be pulled out again by evaporation and capillary action.

There is much evidence suggesting that considerable recharge occurs through the creek and arroyo beds. Sediments in the beds are usually coarser than the soil covering most of the area, as shown in Figure 21.

All of the drainages, then, may contribute to ground-water recharge at some time. The two largest ones, San Mateo Creek and Arroyo del Puerto, may be considered to be major sources of recharge.

San Mateo Creek is the major drainage on the western side of Mt. Taylor, and is naturally supplied by springs on the flanks of the mountain as well as by intermittent runoff along its course. Under normal conditions it flows perennially in San Mateo Canyon before disappearing just west of the town of San Mateo. Under conditions of high discharge it may flow along most of its course to the southwestern corner of the study area.

Extensive dewatering has occurred since the beginning of the construction of the Gulf Mt. Taylor Mine, and discharge into San Mateo Creek has reached thousands of gallons per minute. This, along with the discharge from other mines, has simulated extremely high natural discharge, causing the Creek to flow to a point about 14 mi. (22 km) downstream from San Mateo, in Sec. 1 or 12, T13N, R10W. The absence of a channel south of these sections implies that flow in the major drainage never leaves the area, but either evaporates or infiltrates, recharging the alluvial aquifer.

A teardrop-shaped area is delineated in Figure 22, which, according to air photos and topographic contours, is marked by round depressions and areas of relatively dense vegetation. This area is believed to represent a major discharge site for the alluvial aquifer, formed when stream flow encounters the relatively impermeable beds of the Chinle Formation, below the "pass" through the sandstone outcrops. The area extends directly out from the "pass" despite a jog in San Mateo Creek. The depressions may be controlled by interflow, or a near-surface water table present during especially high discharge in the Creek. The general shape of the area and the situation causing it suggest that it is a ground water equivalent of an alluvial fan.

Evidence suggests that ground water in the alluvial aquifer recharges the underlying bedrock formations, especially where conditions of head and permeability are favorable. Such a case is evident near the town of San Mateo. Water levels from wells in the Menefee Formation (Figure 23) indicate that flow is generally to the northwest, roughly perpendicular to the regional dip of the formation (Plate 3) and following the ground-surface contours. Moreover, the contours indicate the presence of a ground-water ridge corresponding to San Mateo Creek, and implying recharge from it. Figure 24 is a cross-section which parallels the Creek and shows the well depths and ground-water levels in wells tapping the Menefee Formation. Water levels closely follow the ground level, despite well depth. The Menefee is generally considered to be a sequence of sandstones and mudstones which would seem to be hydraulically separate. But, in addition to showing recharge from San Mateo Creek, the water levels in San Mateo suggest that the Menefee behaves as a single hydrologic unit, and may be considered a water table aquifer. This is consistent with the belief of Berry (1959), based on his observation of the Menefee wells north of the study area.

HYDROGEOLOGY AND WATER RESOURCES OF THE AMBROSIA LAKE-SAN MATEO AREA McKINLEY AND VALENCIA COUNTIES, NEW MEXICO

INTRODUCTION

Problem and Purpose

In the southern part of the San Juan Structural Basin, in northwestern New Mexico, the annual precipitation equals approximately 10 in. (inches; 25 cm, or centimeters). The annual evaporation rate, however, may reach 100 in. per year (254 cm; Tuan and others, 1968). Consequently, most of the area lacks adequate supplies of surface water to support even the most basic human needs.

The San Juan Basin is rich in energy resources, especially petroleum, coal, and uranium. The exploration for and mining of these items are active, and are expected to increase as the nation's oil production declines. As energy development continues in the area, and is accompanied by an influx of people, existing and potential problems related to water must be addressed.

Due to the deficiency of surface-water supplies, residents and industry in the area will be dependent upon ground water. At the same time it will be, in many cases, necessary to pump large amounts of ground water to facilitate mining operations. Some of this water will be used for ore-milling, and all of it must be disposed of in such a way that it will not contaminate other water supplies.

HYDROGEOLOGY AND WATER RESOURCES OF THE AMBROSIA LAKE-SAN MATEO AREA McKINLEY AND VALENCIA COUNTIES, NEW MEXICO

ABSTRACT

The Ambrosia Lake-San Mateo area, located approximately 10 miles (16 kilometers) north of Grants, New Mexico, is a major producer of uranium ore. Mining neccesitates the dewatering of approximately 6 billion gallons (23 billion liters) per year from local geologic units. Ground-water information has been obtained for a 15-minute quadrangle-sized area by field investigations, laboratory analyses, and the compilation of published data. Geologically, the study area is typical of the outcrop zone along the southern flank of the San Juan Basin.

Most of the ground water produced in the area is pumped from the uranium-bearing Westwater Canyon Sandstone Member of the Morrison Formation (Jurassic), which yields from 20 to 300 gpm (gallons per minute; 1.3 to 18.9 l/s, or liters per second) to wells. Domestic wells near San Mateo tap the Menefee Formation and Point Lookout Sandstone (Cretaceous), which commonly yield from 20 to 50 gpm (1.3 to 1.5 l/s). The bedrock aquifers have higher yields in the southeastern part of the area, due to more intense fracturing. Ground water flow in the alluvial aquifer is generally to the south. The flow in the bedrock aquifers is to the northeast and east, following the strata's dip and ubiquitous northeasterly-trending fractures. Ground water sampled in the central part of the study area contains from 400 to 2000 mg/l (milligrams per liter) TDS (total dissolved solids). Based on calculations from resistivity logs, it is estimated that ground water in the less developed northeastern part of the area contains from 2000 to 5000 mg/l TDS.

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES, cont.

REFERENCES

18-21

WATER QUALITY DATA for Discharges From Uranium Mines and Mills in New Mexico

NM Health and Environment Department
Environmental Improvement Division
WATER POLLUTION CONTROL BUREAU
July 1980

HEALTH & ENVIRONMENT department

WATER QUALITY DATA FOR DISCHARGES FROM

NEW MEXICO URANIUM MINES AND MILLS

Principal Investigation and Data Collection by:

Maxine S. Goad	Water Pollution Control Bureau, EID
Charles L. Nylander	Water Pollution Control Bureau, EID
Bruce M. Gallaher	Water Pollution Control Bureau, EID
John G. Dudley	Water Pollution Control Bureau, EID
Betty L. Perkins	Energy and Minerals Department

Text Preparation by:

Betty L. Perkins	Energy and Minerals Department
Maxine S. Goad	Water Pollution Control Bureau, EID

WATER POLLUTION CONTROL BUREAU
ENVIRONMENTAL IMPROVEMENT DIVISION
NEW MEXICO HEALTH AND ENVIRONMENT DEPARTMENT
Post Office Box 968
Santa Fe, New Mexico 87503

JULY 1980

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Water Quality Data for Discharges from New Mexico Uranium Mines and Mills

I. INTRODUCTION

A. PURPOSE AND SCOPE OF THIS REPORT

The purpose of this paper is to report on three years of water quality data obtained from samples collected by the New Mexico Environmental Improvement Division (EID) in 1977, 1978, and 1979 at all New Mexico uranium mines known to be undergoing dewatering (including discharge from uranium recovery facilities) and at all operating New Mexico uranium mills. In addition, data for samples collected at two locations from wells completed into the ore bearing formation in areas which are expected to undergo uranium recovery will be reported. For approximate locations of all facilities sampled see figures 1, 2, 3 and 4.

In order to provide a background for understanding the data, general information will be presented on 1) the location and geology of the major ore bodies, 2) the need for dewatering, 3) dewatering techniques and sources of water, 4) water treatment and 5) mine water inflow rates. A brief description of waste liquor generation during milling will be given. The methods used in sample collection will be described. The type of analysis used for each element will be outlined.

TABLE III

HISTORICAL APPROXIMATE* WATER PRODUCTION

FROM NEW MEXICO URANIUM MINING AREAS

Year	gpm Laguna	gpm Smith Lake	gpm Church Rock	gpm Ambrosia Lake	Total gpm	Gallons (million) Total Yr.
1956				500	500	262.8
1957				4,500	4,500	2,365.2
1958				8,500	8,500	4,467.6
1959				11,500	11,500	6,044.4
1960			400	11,500	11,900	6,254.6
1961		60	400	12,000	12,460	6,549.0
1962		85		11,600	11,685	6,141.6
1963		85		11,400	11,485	6,036.5
1964				11,300	11,300	5,939.3
1965				11,000	11,000	5,781.6
1966				9,500	9,500	4,993.2
1967			2,400	8,500	10,900	5,729.0
1968			2,300	8,300	10,600	5,571.4
1969			2,000	8,000	10,000	5,256.0
1970			3,500	8,500	12,000	6,307.2
1971			3,600	8,000	11,600	6,097.0
1972	30		4,000	8,000	12,030	6,323.0
1973	30		4,000	7,500	11,530	6,060.2
1974	100		4,000	7,000	11,100	5,834.2
1975	100		4,250	7,000	11,350	5,965.6
1976	150		4,250	7,400	11,800	6,202.1
1977	200	50	4,500	7,000	11,750	6,175.8
1978	225	200-300	5,400	7,420	13,345	7,014.1
				TOTAL WITHDRAWAL		127,371.4

1956-1978 Total = .39 million acre feet

* Does not include water produced during shaft sinking.

Source: Phillips Exhibit, Hearing before the State Engineer
July 31 - August 2, 1979

cant water from the mine settling ponds (approximately 2500 gpm in 1977, 1978, and 1979) is sent to an ion exchange facility located at the Kerr-McGee mill site. Mining of ore occurs in all mines except Section 22 and 33, which are undergoing mine water recirculation only. Once the water is run through the ion exchange for uranium recovery, it goes to the mill make-up pond. Most of this water is used in the mill and is disposed of with the mill tailings. Any excess water not sent to the mill is treated with $BaCl_2$ and discharged via an outfall to the Arroyo del Puerto. Since there was no discharge at the time of sampling in 1979, only data for 1977 and 1978 are given for this discharge in Table XIV.

Company officials have stated that at one time or another in the past Section 22, 30 and 30W mines have received backfill. They were not receiving backfill during 1977, 1978, and 1979 however.

United Nuclear Corporation Central Ambrosia Lake Mines

UNC's Westwater Canyon Member host rock mines in the central section of Ambrosia Lake (Ann Lee, Section 27 and Sandstone mines) are all undergoing recirculation of mine water to pick up soluble uranium. The discharges pumped from the three mines are collected together in a pond near the ion exchange facility, which is located at the old Phillips mill site. Water from this pond is run through the ion exchange facility (500 to 600 gpm in 1979) and then most of it is recirculated to the mines to leach

Table XV

United Nuclear Corporation IX

Ambrosia Lake

		10/27/77 Outfall to Arroyo	11/17/78 Last Pond	11/07/79 Last Pond
TSS	mg/l	1.1	< 1.0	2.0
TDS	mg/l	1852	1903	2441
cond	μmhos	2657	2241	3288
pH		8.08		8.12
As	mg/l	< .005	< .005	.009
Ba	mg/l	.27	.074	< .100
Se	mg/l	.268	.171	.122
Mo	mg/l	3.20	1.914	3.06
NH_3	mg/l	.015	0	.05
Na	mg/l	427.8	420.9	510.6
Cl	mg/l	108.1	97.5	188.2
SO_4	mg/l	1060	1115	1279.8
Ca	mg/l		148.8	193.6
K			8.19	9.75
bicarbonate	mg/l		227.7	174.0
Cd	mg/l		< .001	< .001
nitrate nitrite	mg/l		.11	< .01
Mg	mg/l			45.3
V	mg/l		< .010	< .010
Zn	mg/l		< .100	< .250
Al	mg/l			< .250
Pb	mg/l		< .005	< .005
gross α	pCi/l		570±70	360±60
Ra-226	pCi/l	29±1	65±1	19±6
Ra-228	pCi/l	0±2		
Pb-210	pCi/l	17±6		
U	mg/l	.32	2.23	1.31

more uranium, and the rest discharged on the surface. There is no $BaCl_2$ treatment.

In 1977 a discharge observed to be taking place to an arroyo near the ion exchange facility was sampled. However several new ponds to contain IX discharge water have been built since then. By 1979 there was only a very intermittent discharge to the ponds as almost all water was being sent back to the mines. In 1978 and 1979 the sample was obtained in the last IX discharge pond. These data are all shown in Table XV.

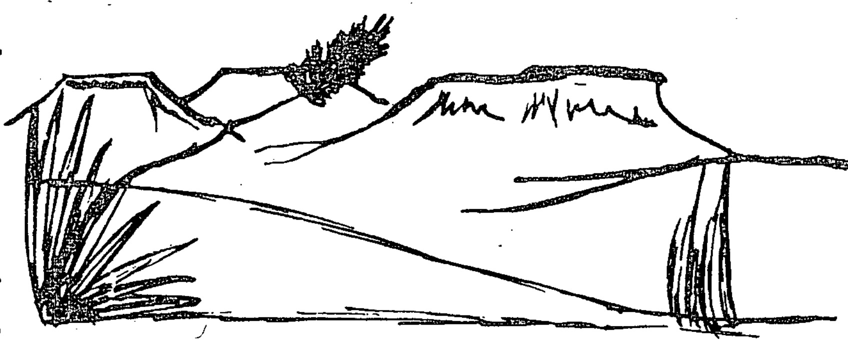
The uranium is stripped from the loaded resin at the IX and the pregnant solution sent to the UN-HP mill near Milan.

There has been no backfilling of these three mines with tailings in the past five years, but it is believed that such backfilling may have been practiced in earlier years.

Kerr-McGee Corporation Section 35 and 36 Mines

While UNC's mines discribed above presently have very little net discharge, Kee-McGee's Section 35 and Section 36 mines, completed in the Westwater Canyon Member, have each averaged discharges of about 1300-1600 gpm 1977-1979. During one short period discharge from section 35 was greatly in excess of this due to a break through into the overlying Dakota Sandstone. However in a 1979

IMPACTS OF URANIUM MINING ON
SURFACE AND SHALLOW GROUND WATERS
GRANTS MINERAL BELT, NEW MEXICO



HEALTH
& ENVIRONMENT
department

contaminant concentrations associated with mine spoils pile runoff may be many of orders of magnitude greater than those associated with the effluents.

CONCLUSIONS

Degree of Contamination

- The analysis presented in this report reveals that discharge of mine dewatering effluents into surface watercourses and runoff from uranium mine spoils piles are significant water quality concerns.

- Uranium mine dewatering effluents have adversely affected surface water chemistry.

  - Affected surface waters contain elevated concentrations of gross alpha radioactivity, uranium, molybdenum, and selenium. These constituents may be found in effluents at concentrations exceeding natural levels by 100 times.

- Dewatering effluents have caused contamination of shallow alluvial aquifers.

  - Some alluvial ground waters have assumed the chemistry of dewatering effluents.

  - This is manifested in changes in the concentrations of total dissolved solids, gross alpha activity, uranium, selenium, and molybdenum, which may exceed natural levels by 10 to 40 times.

- Uranium mine spoils contribute pollutants to surface waters.

  - Spoils from many abandoned and active mines are eroding directly into surface drainages.

  - Mine spoils generate stormwater runoff that contains concentrations of gross alpha and beta activity, uranium, radium-226, lead-210, molybdenum, as well as other metals, that may exceed concentrations in natural runoff by up to 200 times.

- Open pit mining, exclusive of the waste piles generated, has caused increases in dissolved concentrations of gross alpha activity, uranium, and radium-226 in surface water.

- Treatment to remove radium-226 from raw minewaters prior to discharge has been generally effective, but the resulting treatment pond sludges are extremely contaminated with radium-226.

  - If improperly disposed of, these sludges may be eroded into watercourses where they could significantly impact water quality.

EXECUTIVE SUMMARY

The Grants Mineral Belt in northwest New Mexico has been, from the 1950s until recently, the major uranium-producing region in the United States. In 1980, there were 40 operating and about 100 abandoned or inactive uranium mine sites in the area. Because of the potential for regional-scale water quality impacts from these activities, the U.S. Environmental Protection Agency funded a multi-year study to evaluate the severity of the impacts and to assess the need for water pollution regulatory changes.

PRINCIPAL GOALS OF THE STUDY

- To describe and assess impacts of disposal of uranium mining wastes on the quality of surface waters and shallow ground waters in the Grants Mineral Belt.
- To evaluate strategies for controlling water pollution from uranium mining sources in the study area.

PRINCIPAL POTENTIAL SOURCES OF CONTAMINATION

Large volumes of liquid and solid wastes are disposed of on the land surface through the mining process. These wastes contain generally low levels of metals and radioactivity, but they nonetheless may be harmful to humans or livestock if ingested over a sustained period of time.

Mine Dewatering Effluents

Because most uranium ore deposits in the Grants Mineral Belt are below the regional water table, ground water must be controlled by pumping to prevent mines from flooding. Both underground and surface mines discharge this water to natural watercourses that are normally dry. Prior to its release, the discharged water (effluent) is treated to reduce the concentrations of radium, uranium, and suspended solids.

Potential impacts to water resources from such discharges are regional in scale. Continuous surface water flows from the mines may be sustained for distances as great as 60 miles. In 1980, a total length of more than 140 miles of naturally dry watercourses were continuously affected by Grants Mineral Belt discharges. The year-round presence of the effluents in the channels greatly has increased use of the water for livestock supply.

Mine Spoils Piles

Mining is done by excavating surface pits or underground shafts and tunnels to gain access to the ore. Waste rock and rock with uneconomical levels of uranium ore are stored at the surface as a waste pile. No reclamation is required or proposed at most mines, and wastes remain on the surface when mining ceases.

The potential for near-surface water quality problems to arise from the spoils is limited in time and area. Erosion of waste pile materials into watercourses largely occurs during periods of natural stormwater runoff. Because of the infrequency of such runoff events, the effects of the waste piles are more localized than those associated with the mine dewatering effluents. On the other hand, the

Potential Impacts of Contamination on Water Uses

- The chemical quality of much surface water and shallow ground water is inconsistent with regional water uses as a result of disposal of wastes from uranium mines in the Grants Mineral Belt.

  - Locally, precipitation runoff from uranium mine spoils is not suitable for ingestion by livestock; such waters may contain elevated concentrations of gross alpha activity, radium-226, arsenic, cadmium, lead, selenium and vanadium.

    Treated mine dewatering effluents may not be suitable for livestock watering, irrigation, or domestic water supply due to consistently high selenium and radium-226, and sometimes to total dissolved solids, molybdenum, arsenic, barium, sulfate, and vanadium.

    Shallow alluvial ground water along San Mateo Creek in the Ambrosia Lake Mining District has been chemically impaired for use in irrigation, livestock watering, and domestic supply because of elevated concentrations of molybdenum, selenium, and gross alpha activity. Along the Puerco River in the Church Rock Mining District, data are less conclusive, but similar impacts are suggested.

Regulatory Authority

- Two regulatory and administrative tools are presently available to the EID to improve controls on uranium mine dewatering effluents.

  - The existing National Pollutant Discharge Elimination System (NPDES) permitting program, run by the U.S. Environmental Protection Agency (EPA) with state certification, is probably the best available mechanism to control mine dewatering effluents. However, the NPDES is presently not as effective as it might be in controlling these effluents.

  - The New Mexico Regulations for Discharge to Surface Waters are not now an effective alternative for control of mine dewatering effluents because these regulations do not specify limits for any trace element or radionuclide.

- Surface water contamination resulting from uranium mine waste piles may be addressed by several legal means, although most are of uncertain applicability.

  - Presently, the best option for control of uranium mine waste piles is that portion of the New Mexico Water Quality Control Commission (WQCC) regulations governing disposal of refuse in a watercourse; this provision has precedent for such use.

  - Federal Superfund clean-up provisions may assist in reclamation of some of the more serious piles near population centers; other provisions of Superfund authorize EPA to compel cleanup of other sites and allow state suits for recovery of response costs and damages to natural resources. Current applicability of the federal Resource Conservation and Recovery

Act (RCRA), the state Abandoned Mine Reclamation Fund, and the state Radiation Protection Regulations is limited.

- Minewater treatment pond sludges contain large concentrations of radium-226 and other radionuclides.
  - At present, regulation of minewater sludges is inadequate.

RECOMMENDATIONS

- The EID should coordinate with the EPA so that new and renewal NPDES permits for uranium mine dewatering effluents in New Mexico include numeric effluent limits for radium-226 and other constituents that affect downstream uses of these waters.
- The New Mexico Regulations for Discharge to Surface Waters should be amended to include comprehensive numeric limits for constituents regulated by NPDES and for other constituents necessary to protect water quality for domestic and agricultural uses.
- Removal or stabilization should be pursued for the largest uranium mine waste piles eroding directly into surface drainages. The EID should require these actions based upon the provision in the WQCC Regulations regarding disposal of refuse in watercourses.
- If necessary, reclamation of uranium mine waste piles could also be pursued under Superfund or the Abandoned Mine Reclamation Fund.
- Waste piles generated by future uranium mining activity must be regulated. This may be accomplished by EPA through the Resource Conservation and Recovery Act. If not, the EID should pursue amendment of the New Mexico Radiation Protection Regulations to extend their applicability to mine wastes.
- The EID should pursue control of minewater treatment sludges. If RCRA regulations are found to be not applicable, then EID should seek to amend the New Mexico Radiation Protection Regulations to control these sludges.

PREFACE

This assessment was initiated to gather technical and legal inforamtion for regional water quality planning purposes. As a result, much of the study design focused on describing potential water quality impacts that may be common to most of the uranium mining industry. Much more detailed work would have to be performed before comprehensive impacts of a specific mining facility could be identified.

In a similar sense, in areas where ground water contamination was detected, no attempts were made to delineate the entire areal extent of contamination. Therefore, no estimates are made of the total volume of waters affected by industry activities.

Information in this report pertaining to regulatory requirements (Chapters X and XI) reflects conditions that existed at the end of 1985.

ACKNOWLEDGEMENTS

This study was undertaken by the New Mexico Environmental Improvement Division through grants under section 208 of the Federal Clean Water Act from the U.S. Environmental Protection Agency.

The authors extend their gratitude to the Navajo Tribe, the U.S. Bureau of Land Management, and to the Lee, Otero, Roundy and Sandoval families for their cooperation and assistance in allowing the EID to drill monitor wells and sample ground water on their properties. Numerous individuals in the uranium industry kindly provided their cooperation, criticisms and suggestions to the EID during the course of field and office visits.

Many EID personnel assisted in the field work, and report preparation and review. Particularly generous with their expertise and support were Mr. Don Ditmore, Mr. Steven Oppenheimer and Dr. Douglas Schneider. Don was present on many sampling trips and performed all of the computer data entry and STORET statistical analyses. Steve was involved in most of the drilling activities. Doug's five years of contributions to the overall project direction and, finally, to the report writing and editing can hardly be emphasized enough. Chapter IX was prepared entirely by Dr. Schneider. Mr. Pat Longmire is also acknowledged for his assistance in interpreting the geochemical computer modeling results.

Appreciation is expressed to the EID professionals in the Milan and Gallup field offices who assisted in collecting stormwater runoff samples.

We are greatly indebted to Ms. Patsy Sandoval for word processing this report and to Ms. Gigi Bayless for drafting the figures.

CONTENTS

FIGURES

TABLES

The New Mexico Environmental Improvement Division's regional assessment of uranium mining impacts is an outgrowth of active public and governmental interest in the environmental consequences of uranium industry activities in the Grants Mineral Belt in the mid-1970's. This interest was sparked by a joint U.S. Environmental Protection Agency-New Mexico Environmental Improvement Agency investigation of water quality. After the results of this state-initiated investigation were published by the U.S. Environmental Protection Agency in September 1975 as **Water Quality Impacts of Uranium Mining and Milling in the Grants Mineral Belt,** New Mexico governmental agencies assessed their knowledge of environmental, economic, and social conditions in the Grants Mineral Belt and identified areas for further research. More specifically, the Environmental Improvement Agency established its Grants Mineral Belt Task Force in 1976 to examine the wide range of environmental concerns associated with uranium development, including impacts on air and water quality, radiation and toxic chemical pollution, the adequacy of regulatory authority, and problems related to expanding population within the region.

Investigation of environmental impacts of the uranium industry was made a priority by the Environmental Improvement Agency in July 1976. One of the areas identified for further research by the Grants Mineral Belt Task Force was the water quality impacts of discharged minewaters (the mines lie within aquifers) on surface watercourses and underlying shallow alluvial aquifers. The decision was made to study such impacts with funding from the grant for water quality planning then being awarded to New Mexico under Section 208 of the federal Clean Water Act. Ultimately, study of water quality impacts was carried out under all three Section 208 grants received by the New Mexico Environmental Improvement Agency (after April 1978, the Environmental Improvement Division) supplemented with state funds.

The regional assessment was designed and initiated by John G. Dudley. After he left the agency in 1980, the project was carried to its conclusion by Bruce Gallaher, joined later by Steven Cary. Credit must be given to Bruce Gallaher and Steven Cary for their reevaluation on the scope and direction of the project. As a result information on runoff was collected both from areas unaffected by uranium mining and from mine waste piles and increased emphasis was given to collection data on total contaminant concentration as opposed to dissolved contaminant concentrations.

The major focus on the assessment is on the minewaters discharged to surface watercourses. The effect these have had on altering ephemeral watercourses to perennial, though artificially maintained, streams is examined as in the relation between surface flow and recharge of underlying shallow, alluvial aquifers. The discharge minewaters are characterized chemically and chemical impacts on both surface water quality and on alluvial ground water quality are assessed.

The regional assessment of uranium mining impacts, however, is much more than simply a study focused on mine dewatering. In order to evaluate the significance of dewatering, natural water quality (i.e., water quality unaffected by uranium industry mining or milling) had to be characterized. Sampling was not limited to perennially flowing streams and ground waters. As the water natural in such Grants Mineral Belt watercourses as the Puerco River, Arroyo del Puerto, and San Mateo Creek results from runoff, storms and snowmelt, natural runoff was sampled as well. In the Grants Mineral Belt, though, runoff may also result from areas affected by the uranium industry. Since mine waste piles have a potentially substantial effect on stream quality, characterization of natural runoff led to characterization of mine waste pile quality.

Field work for the regional assessment was performed over the period from 1977 to 1982. During the period from 1978 to 1980, processed uranium production peaked in the Grants Mineral Belt. Production declined in 1981, though it was still substantially higher than pre-1978 production, but by 1982 production had declined considerably to levels similar to the mid-1950's when the industry started in New Mexico. today, only the Homestake Mining Company mines, the Kerr-McGee (Quivera Mining Co.) Ambrosia Lake mine, and the Gulf Mt. Taylor mine are discharging minewaters in the Ambrosia lake mining district. Similarly, the only dewatering in the Church Rock district is from the Kerr-McGee (Quivera Mining Co.) Church Rock mines. No other mines in the Grants Mineral Belt are still dewatering.

That this assessment has been brought to fruition is the result of collective efforts of many individuals. Officials in both the regional office in Dallas and the Washington, D.C. headquarters of the U.S. Environmental Protection Agency have given support and encouragement. David Miller of Geraghty and Miller, Inc. provided guidance when the direction of the assessment was being reassessed. But more importantly this assessment represents the efforts of too many present and former members of the Environmental Improvement Division to acknowledge then all individually, or perhaps even to remember all their efforts. At the same time, it would not be fair not to acknowledge those individuals whose efforts have contributed most prominently to this assessment. Besides the already mentioned Steven Cary, John G. Dudley, and Bruce Gallaher, these include Catherine Callahan, Patrick Longmire, Charles Nylander, Steven Oppenheimer, Michael Snavely, and Richard L. Young. Lastly I coordinated the production of the final report and contributed substantially to its writing and editing and thus must accept part of the responsibility for the contents.

Douglas L. Schneider
Water Quality Planning Section
Environmental Improvement Division

List of Abbreviations

EIB, NM EIB	New Mexico Environmental Improvement Board
EID, NM EID	New Mexico Environmental Improvement Division
EPA, U.S. EPA	U.S. Environmental Protection Agency
NAS/NEA	National Academy of Sciences-National Academy of Engineering
WQCC, NM WQCC	New Mexico Water Quality Control Commission
mg/l	milligrams per liter
ug/l	micrograms per liter
pCi/l	picocuries per liter
cfs	cubic feet per second
TDS	total dissolved solids
TSS	total suspended solids
Ca	calcium
K	potassium
Mg	magnesium
Na	sodium
Cl	chloride
CO_3	carbonate
HCO_3	bicarbonate
SO_4	sulfate
As	arsenic
Ba	barium
Cd	cadmium
Mo	molybdenum
Pb	lead
Se	selenium
U,U-natural	uranium, natural uranium
V	vadadium
Zn	zinc
gross alpha	gross alpha particle activity
gross beta	gross beta particle activity
Pb-210	lead-210
Po-210	polonium-210
Ra-226, Ra-228	radium-226, radium-228
Th-228, Th-230, Th-232	thorium-228, thorium-230 thorium-232

I. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

A. Uranium mine dewatering effluents have altered surface water chemistry.

Uranium mine dewatering has transformed ephemeral arroyos into perennial streams. In natural runoff, trace elements and radionuclides are primarily associated with suspended sediments and precipitates. In treated minewaters, trace elements and radionuclides are usually present in the dissolved form. Dissolved gross alpha activity in dewatering effluents exceeds levels in natural runoff by up to 100 times. Molybdenum, selenium, and uranium are consistently higher in minewaters than in natural runoff. Arsenic, barium, and vanadium are occasionally elevated as well.

Uranium, molybdenum, selenium, and principal dissolved salts generally are not attenuated in channels that receive minewaters; instead they remain in solution. In drainages that are relatively sediment-free such as Arroyo del Puerto, radium-226 and lead-210 tend to stay in solution. However, most regional watercourses have plentiful sediment; under these circumstances radium-226 and lead-210 in minewaters are usually lost from solution shortly after their release. In sediment-rich streamflows, sediments carrying minewater contaminants are diluted by clean sediments and levels of radioactivity associated with arroyo sediments eventually become indistinguishable from natural conditions.

B. Uranium mine dewatering effluents have contaminated shallow alluvial ground waters.

Infiltration of large volumes of dewatering effluents has changed the chemistry of shallow alluvial ground waters. In reaches where stream-bottom leakage is great, alluvial ground waters now bear a stronger chemical resemblance to minewaters than to natural surface waters. This change is particularly evident in terms of general ionic chemistry and total dissolved solids. Trace minewater constituents that remain in solution, such as uranium, selenium, and molybdenum, are also found in shallow ground waters in concentrations approaching those of undiluted minewaters. Alluvial aquifers recharged primarily by dewatering effluents have thus assumed the chemistry of the minewaters.

Dewatering effluents have had these effects on alluvial ground water throughout the GMB. Locally, concentrations of uranium, molybdenum, selenium, and gross alpha activity exceed natural levels by 10 to 40 times. Ground water degradation is most pronounced in the Ambrosia Lake Mining District because most mine dewatering has occurred there, the chemical quality of minewaters is poor, and alluvium in local drainages promotes infiltration. Effluents have degraded the Puerco River alluvium with trace elements and radionuclides, but not to the same degree as in Ambrosia Lake. Limited impacts are attributable to low infiltration rates along the Puerco River.

Contaminant concentrations in shallow ground water may be mitigated through dilution, adsorption, cation exchange, and chemical equilibrium. Because uranium, molybdenum and selenium all tend to form anions in solution, these constituents are mobile in the subsurface and their concentrations are unlikely to be reduced except by dilution with cleaner water. Moreover, geochemical computer modelling suggests that uranium concentrations in regional alluvial aquifers will not decline solely as a result of long term chemical equilibrium adjustments. In contrast, radium-226 forms a cation in solution. Consequently, it is attenuated so effectively in regional alluvium that infiltration of minewaters has increased the dissolved radium-226 content of shallow ground water only by about 0.1 pCi/l.

C. Uranium mine spoils piles adversely affect the quality of surface waters.

Ten to 20 abandoned mines, as well as some large active mines, have waste piles that are eroding directly into local drainage channels. Although suspended sediment concentrations in mine-waste runoff are similar to natural sediment loads, mine-waste runoff contains contaminants in concentrations that exceed natural levels by up to several hundred times. Uranium mine waste piles are major contributors of heavy metals to surface waters; uranium and molybdenum are of the greatest regional concern, while arsenic, selenium, and vanadium may be locally elevated. Of even greater significance are several radioactivity parameters: gross alpha activity in mine waste runoff exceeds natural activity by up to 200 times; levels of natural uranium and radium-226, two major alpha emitters, exceed natural runoff levels by over 100 times; and gross beta activity and its chief contributor, lead-210, are also far in excess of natural runoff levels. In spite of the high contaminant concentrations in waste-pile runoff, however, the limited duration of these runoff events moderates the potential for regional scale contamination to occur.

Open pit mining, exclusive of waste piles, has caused degradation of water quality in the perennial Rio Paguate. The greatest increases in dissolved concentrations were exhibited by radioactive constituents: gross alpha activity, radium-226, and natural uranium. There were no statistically significant increases in dissolved trace element concentrations, except for uranium. Impacts on the Rio Paguate of stormwater runoff from open pit mine waste piles was not evaluated, but is probably similar to the effects identified at other waste piles.

D. Widespread treatment of raw minewaters to remove radium-226 has been generally effective in improving the quality of minewater effluents, but the resulting treatment pond sludges are extremely contaminated.

Raw minewaters may contain elevated concentrations of several constitutents, such as gross alpha and beta activity, radium-226, lead-210, uranium, molybdenum, selenium, sulfate, total dissolved solids, and occasionally barium, arsenic, and vanadium. Treatment of these waters through coagulation and settling reduces concentrations of radium-226 and uranium by many fold. However, large influxes of dissolved radium-226 may be introduced to surface waters during treatment process failures. Moreover, sludges which accumulate in minewater treatment pond bottoms are highly concentrated in radium-226, and may require special disposal practices.

E. As a consequence of uranium mining in the GMB, the chemical quality of much surface and ground water is inconsistent with regional water uses.

Stormwater runoff from uranium mine waste piles is definitely not suitable for watering livestock. Total unfiltered concentrations of arsenic, cadmium, lead, selenium, vanadium, gross alpha activity and radium-226 are not consistent with ingestion of this water by livestock. The quality of natural runoff in the Ambrosia Lake Mining District admittedly is poor, but the quality of mine waste pile runoff is worse. This conclusion is also expected to apply in the Church Rock mining district.

While certain radioactivity parameters are elevated in the Rio Paguate below the Jackpile open pit mine, overall water quality both upstream and downstream of the mine is consistent with livestock use.

Treated minewaters may not be suitable for livestock watering, irrigation or domestic water supply. The chief constituents rendering minewaters unsuitable for livestock watering are selenium and radium-226. Principal constituents making minewaters undesirable for irrigation include selenium, radium-226, molybdenum, and total dissolved solids. Minewaters are generally unsuitable for domestic water supply because of elevated levels of selenium, radium-226, and total dissolved solids. Other constituents, such as arsenic, barium, sulfate, and vanadium, may be problematic locally. In general, treated minewaters in the Ambrosia Lake District are of poorer quality than those in the Church Rock District.

* The shallow alluvial aquifer along San Mateo Creek has definitely been chemically impaired for use in irrigation, watering of livestock, or domestic water supply. Molybdenum, selenium, and gross alpha activity are found at high enough concentrations to render this water unsuitable. Along the Puerco River, conclusions are less obvious because the alluvium is less permeable and a uranium mill tailings spill has obscured some minewater impacts. Nevertheless, selenium and molybdenum levels in one well suggest that ground water uses along the Puerco River may be impaired.

F. Several regulatory tools, in place or anticipated, may be useful in controlling uranium mining impacts on regional water resources.

Appropriate water pollution control statutes are the federal Clean Water Act (CWA) and the New Mexico Water Quality Act (WQA). Other statutes that may bear on the effort to protect water resources in the GMB include the New Mexico Radiation Protection Act (RPA), the federal Resource Conservation and Recovery Act (RCRA), the federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the New Mexico Abandoned Mine Reclamation Act (AMRA).

The National Pollutant Discharge Elimination System (NPDES), authorized by the CWA, has not yet proved to be an totally effective means to regulate minewater discharges. First, key minewater constituents, such as selenium and molybdenum are not covered. Second, legal challenges by mine operators have caused many permits to be temporarily stayed, during which time they are unenforceable. Technically, the EID can add parameters to NPDES permits via the state certification process. However, development of limitations for toxic trace elements in minewater discharges is hampered by state surface water quality standards and procedures that are technically burdensome and of uncertain applicability.

State of New Mexico regulations, promulgated under the Water Quality Act, have also been ineffective in controlling minewater discharges. Virtually all key minewater constituents, including uranium and radium-226, have remained uncontrolled under these regulations.

Control of contamination by solid mine wastes, including pond sludges, may be best achieved through application of regulations promulgated under the Water Quality Act. One provision of this Act prohibits disposal of refuse in a natural watercourse. Further, this provision has precedent for use in compelling cleanup of molybdenum and copper mine wastes.

Uranium mine wastes are not adequately covered by the Abandoned Mine Reclamation Act, the Radiation Protection Act or the Resource Conservation and Recovery Act. The AMRA will probably not be used in the immediate future for addressing water quality problems associated with uranium mines. However, both the Radiation Protection and the RCRA regulations could be amended to cover such materials. The EPA is presently studying just such proposed changes to the RCRA.

At the present time, the Comprehensive Environmental Response, Compensation and Liability Act is generally anticipated to have limited utility in ameliorating problems associated with uranium mine wastes in New Mexico, at least as far as Superfund-financed cleanups are concerned. However, CERCLA empowers U.S. EPA to enforce against site owners in order to compel cleanup. Also, CERCLA authorizes legal action by states against site owners in order to recover response costs and damage to natural resources.

RECOMMENDATIONS

Analysis of water quality impacts of uranium mining in the Grants Mineral Belt has revealed three major concerns that require regulatory or administrative action. In order of importance, these three major concerns are: discharge of mine dewatering effluents into ephemeral surface waters; stormwater runoff from unreclaimed uranium mine waste piles; and the potential for radionuclide-rich minewater treatment sludges to enter surface watercourses. Surface waters and associated alluvial ground waters are potentially affected. A variety of regulatory and administrative tools may be useful in addressing these concerns. Specific recommendations are discussed below.

A. Uranium Mine Dewatering Effluents

1. New and renewal NPDES permits for discharge of uranium mine dewatering effluents in New Mexico should incorporate stringent numeric effluent limitations for radium-226 and other parameters related to downstream uses of these waters. Such effluent limitations may be incorporated in permits through state certification by the EID or through case-specific analysis by the EPA. Needed effluent limitations can be developed only after consideration of present water uses, likelihood of future uses, and available water treatment technologies. Successful implementation of this recommendation will require coordination between the EID and the EPA.

2. The New Mexico Regulations for Discharges to Surface Waters should be substantially amended to serve as an effective mechanism for regulating discharges of uranium mine dewatering effluents to surface watercourses. Amendments should include comprehensive numeric discharge limits, not only for those chemical constituents regulated by NPDES, but for all constituents necessary to protect water quality for agricultural and domestic use.

B. Unreclaimed Uranium Mine Waste Piles

1. Removal or stabilization should be implemented at the largest uranium mine waste piles eroding directly into surface drainages. Priority sites include the Old San Mateo Mine near San Mateo Creek and the Jackpile-Paguate mine areas along the Rio Paguate. These actions could be based on the provision of the WQCC regulations regarding Disposal of Refuse (Section 2-201). State suits under CERCLA then should be used to recover cleanup costs. Alternatively, the EID could pursue cleanup using EPA enforcement under CERCLA, or using state resources acquired through state suits under CERCLA.

2. The EID should postpone action to regulate future uranium mine waste piles directly. It is anticipated that the EPA will decide during 1986 whether to regulate uranium mine waste under RCRA. Should the EPA decide not to regulate mine waste piles under RCRA, the EID should recommend that the EIB amend the New Mexico Radiation Protection Regulations to extend their applicability to mine waste piles.

C. Minewater Treatment Pond Sludges

1. If the U.S. EPA chooses not to regulate mine wastes under RCRA, the EID should recommend that the EIB amend the New Mexico Radiation Protection Regulations to control these sludges fully and effectively.

VI. HYDROLOGIC EFFECTS OF MINE DEWATERING EFFLUENTS

Disposal of uranium mine dewatering effluents in the normally dry arroyos of the Grants Mineral Belt has had a significant impact on regional surface waters and ground waters. Where dewatering occurs, ephemeral streams are transformed into perennial streams. The artifically supplied perennial streams have dramatically increased the volume of water that recharges underlying alluvial aquifers. The added recharge has raised water tables and increased the amount of ground water that can be easily obtained from shallow wells. As a result, more near-surface ground waters and surface waters are available.

6.1. HISTORY

The history of uranium mine dewatering has been summarized by Perkins and Goad (1980). In general, dewatering has been performed continuously in the region since at least 1956. The Church Rock and Ambrosia Lake mining districts have witnessed the largest volume of mine dewatering. Water production from mines in the Ambrosia Lake district has been continuous since 1956, with peak production in the early 1960s. Significant dewatering in the Church Rock area began in 1967 and peaked about 1980. Decline of the industry since 1980 has caused several mines to close and the flow of dewatering effluents to diminish in both the Ambrosia Lake and Church Rock districts. Some mines which are not extracting ore, however, have been placed on "stand-by status" and continue dewatering operations. Figure 6.1 illustrates the history of minewater production in the Grants Mineral Belt through 1982.

6.2. HYDROLOGIC IMPACTS ON REGIONAL SURFACE WATERS

6.2.1. General Characteristics of Flow Before and During Mine Dewatering

Prior to dewatering of underground uranium mines in the 1950s and 1960s, the regional drainages were ephemeral. These streams experienced an wide range of discharges, from zero flow to large flash floods (e.g., Busby, 1979). Maximum discharges of flash floods often reach several thousand cubic feet per second (cfs) (Thomas and Dunne, 1981). The only significant perennial waters in the region are a few small springs along the Puerco River, and perennial streams draining the north and east flanks of Mt. Taylor.

Discharges of uranium mine dewatering effluents have transformed several ephemeral streams to perennial streams flowing for many miles. Minewaters have provided perennial baseflow for Pipeline Arroyo and the Puerco River in the Church Rock mining district, and Arroyo del Puerto and San Mateo Creek in the Ambrosia Lake mining district. Other newly created perennial streams occur in other regional mining districts not covered by this report. Table 6.1 presents approximate average distances that perennial flow conditions are sustained by various mine discharges during 1979-1981. The greater distances occur along river reaches where stream bottom leakage rates are relatively low.

Before mine dewatering, flow in the Puerco River, for example, was distinctly seasonal (Figure 6.2). One season of flow was late winter (February through April) a time of gentle frontal precipitation and melting snow. May and June were months of little or no precipitation and low stream flow in the Puerco River. The second season of flow was middle-to-late summer (July through October). Summers in the region are usually characterized by frequent, intense, and isolated thunderstorms that can produce large

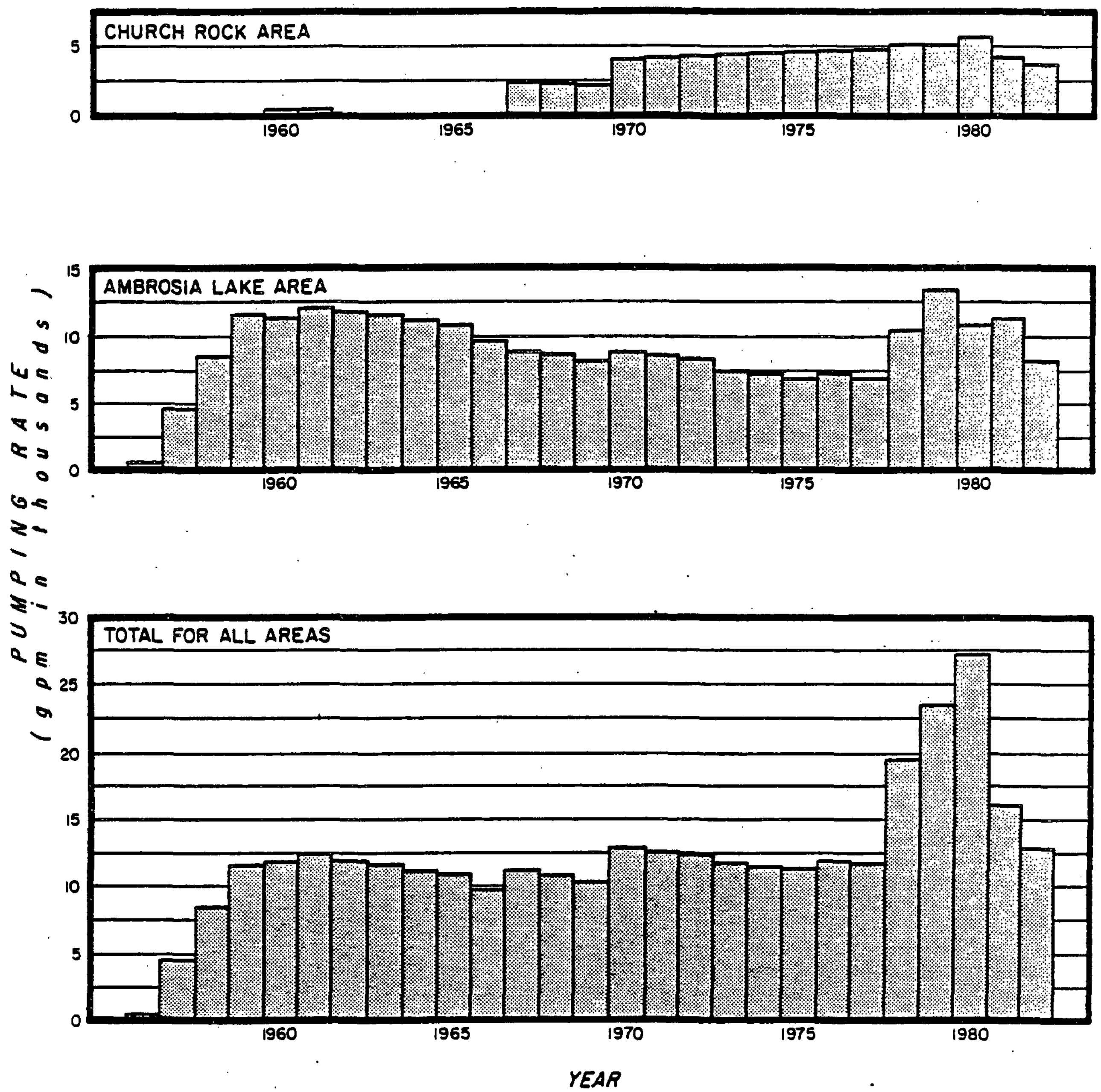


FIGURE 6.1 Water production by uranium mines, Grants Mineral Belt.

TABLE 6.1 Approximate Average Distances of Constant Flow below Mine Discharges, 1979-1981. Location of mining districts shown on Figure 2.1.

DRAINAGE CHANNEL	VOLUME OF DISCHARGE (gallons per minute)	APPROXIMATE DISTANCE OF FLOW* (miles)
	Church Rock Mining District	
Puerco River	5000	50
	Ambrosia Lake Mining District	
Arroyo del Puerto	2300	5
San Mateo Creek	1500	3
	Mt. Taylor Mining District	
San Lucas/Arroyo Chico	4000	40
	Crownpoint Mining District	
Kim-me-ni-oli Wash	3400	20
	Marquez Mining Area	
Rio Marquez	1000	15
Rio Salado	1000	10

*Distances are based on the authors' observations, review of EID files, and U.S. Geological Survey annual water data reports.

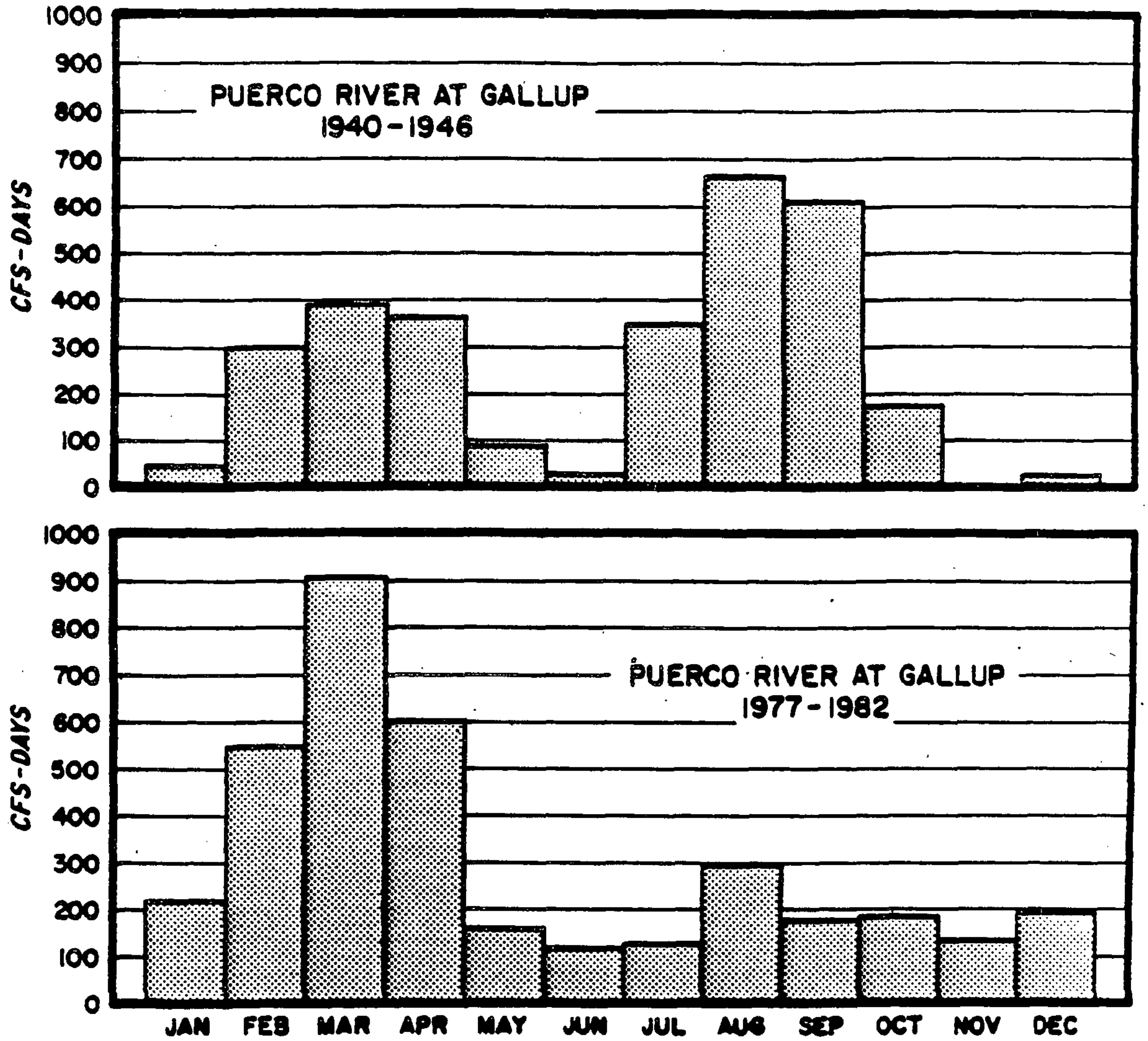


FIGURE 6.2 Monthly flow in the Puerco River at Gallup before mine-dewatering and with flow augmented by mine dewatering

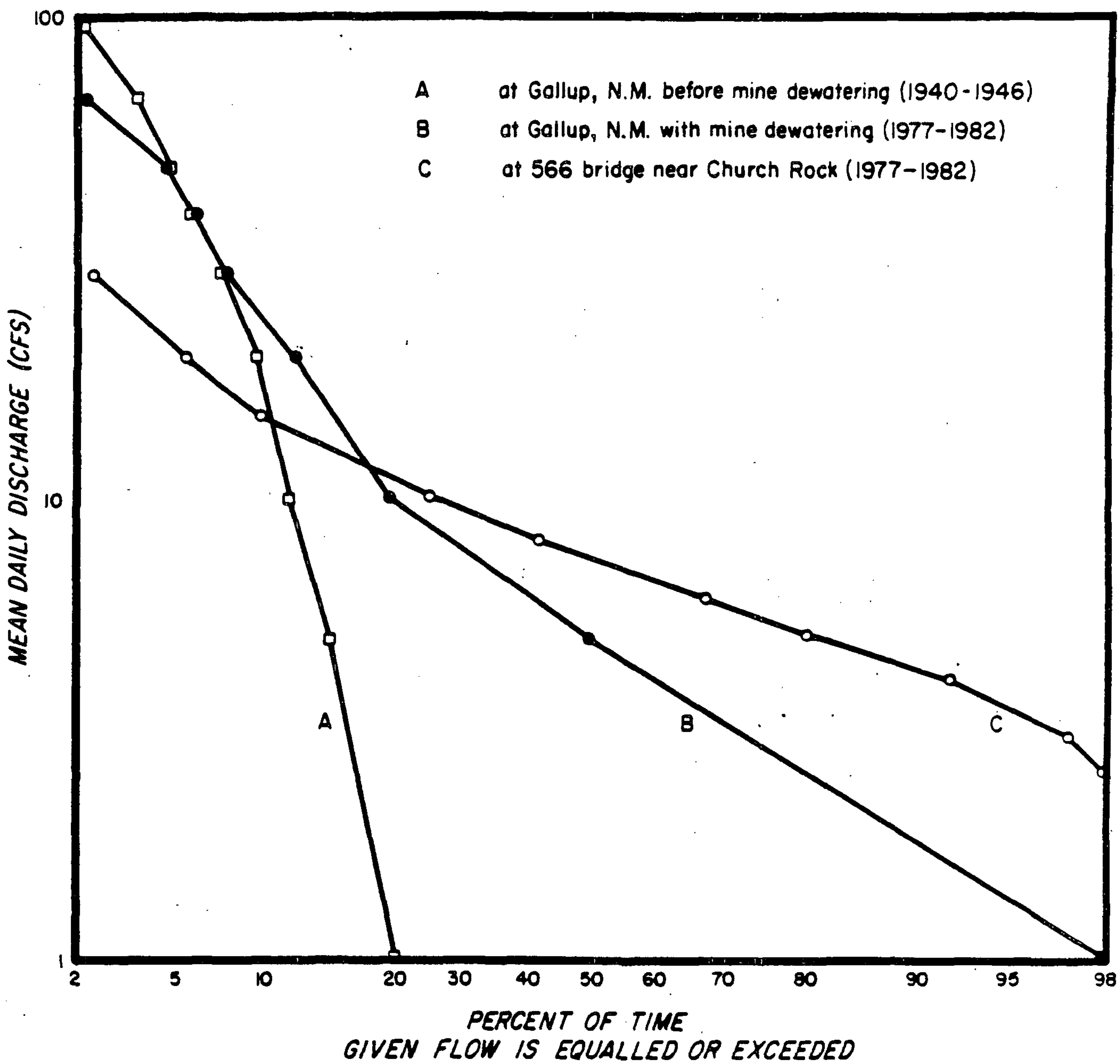


FIGURE 6.3 Flow duration curves for the Puerco River before mine dewatering and with mine dewatering

flash floods. Autumn months of November through January were once again dry, in terms of both precipitation and stream flow.

With ongoing mine dewatering, flow in the Puerco River become continuous. Figure 6.2 shows that climatic dry seasons (May through June and November through January) are no longer times of no flow in the Puerco. Whereas during these months in the 1940s the Puerco River was often without flow, between 1977 and 1982 the river was never dry and flow at all months averaged at least 120 cfs-days.

Figure 6.2 depicts augmented late winter stream flows, but few high flows in middle-to-late summer. The dearth of summer high flows in recent years reflects the failure of significant summer thunderstorms to materialize over the basin from 1978 to 1981. These storms returned in 1982 and 1983. A longer period of record would probably show the continued presence of the two high flow seasons that typified the pre-mining era.

6.2.2. Characteristics of Low Flows

Flow duration curves constructed for daily discharges in the Puerco River for the periods 1940 to 1946 and 1977 to 1982 further demonstrate the change in low flow conditions attributable to the continuous discharges of uranium mine dewatering effluents (Figure 6.3). Prior to mine dewatering, streamflow in the Puerco River at Gallup was greater than 1 cfs only 20 percent of the time (Curve A). In fact, the stream was normally dry. Since mine dewatering, however, the Puerco River has been perennial. The median discharge (that flow that has been equalled or exceeded 50 percent of the time) is now about 5 cfs at Gallup (Curve B) under the new artificial flow regime.

The Pipeline Arroyo/Puerco River system is now perennial from the Church Rock mines to as far as Arizona, a distance of about 50 river miles. Eventually, unless naturally augmented, all surface flow is lost to infiltration, evaporation, and transpiration. Comparison of median flow at Church Rock (Curve C) and Gallup (Curve B) suggests that about 2.5 cfs of flow is lost between these two gages. As the Puerco River continues into Arizona, its flow eventually becomes intermittent and then ephemeral.

6.2.3. Annual Water Yield

Annual water yield, or the yearly volume of surface flow, in the Puerco River at Gallup has increased substantially because of mine dewatering (Table 6.2). The logarithmic mean annual water yield at Gallup was about 1900 cfs-days in the 1940s. This is assumed to be representative of pre-mining conditions. The years 1977-1982 exhibit a logarithmic mean annual water yield of about 3400 cfs-days. These years, therefore, exhibit a 78 percent increase in water yield over pre-mining conditions.

TABLE 6.2 Annual discharge for the Puerco River at Gallup before Mine Dewatering and with Flow Augmented by Mine Dewatering in cfs-days. Source: USGS.

	BEFORE MINE DEWATERING		WITH MINE DEWATERING	
	Water Year	Annual Discharge	Water Year	Annual Discharge
	1940	7,283	1978	1,502
	1941	1,459	1979	5,656
	1942	2,893	1980	5,463
	1943	741	1981	2,702
	1944	3,264	1982	3,446
	1945	645		
Log Mean		1,906		3,366

Although no stream flow data exist for San Mateo Creek before mine dewatering, flow records for 1977 through 1982 include periods both of active discharge to San Mateo Creek and of no discharge. Dewatering was ongoing in 1977, when flow measurement in San Mateo Creek began. At that time, about 2900 gallons per minute of dewatering effluents were released to San Mateo Creek (Perkins and Goad, 1980). Beginning in spring 1978, however, virtually all effluents were diverted for irrigation and to an adjacent drainage basin and did not reach San Mateo Creek. The impact of this diversion on flow in the stream can be seen in Figure 6.4. It is clear that the dewatering effluents maintained a small perennial stream at the gage site. Without the minewaters, flow in San Mateo Creek at the gage site is much reduced and ephemeral.

6.3 HYDROLOGIC IMPACTS ON REGIONAL GROUND WATERS

Streams created by the discharge of dewatering effluents are, with the possible exception of a few reaches, losing flow to the subsurface. While some surface flow is evaporated or transpired, a large volume infiltrates into the arroyo beds, and thereby recharges the shallow alluvial aquifers of the Puerco River, Arroyo del Puerto, and San Mateo Creek, among others.

Rates of infiltration were probably greater at the onset of mine dewatering than they are today because of a gradual "filling" of available storage in the alluvium. Infiltration rates along Arroyo del Puerto and San Mateo Creek are rapid Relative to the Puerco River, due to an abundance of sandy material in San Mateo Creek and because of influences of underlying dewatered bedrock aquifers. Gaging data indicate average stream bed losses along the San Mateo Creek of approximately 0.72 m^3/min/km, as compared with bed losses along the Puerco River of about 0.24 m^3/min/km (EPA 1983).

Infiltration has been estimated to range from at least 90 percent to perhaps 99 percent of mine discharge (EPA, 1983). A review of flow records from the Church Rock mining district showed seepage losses of 7.5 m^3/min in October 1975, and 7.25 m^3/min in July

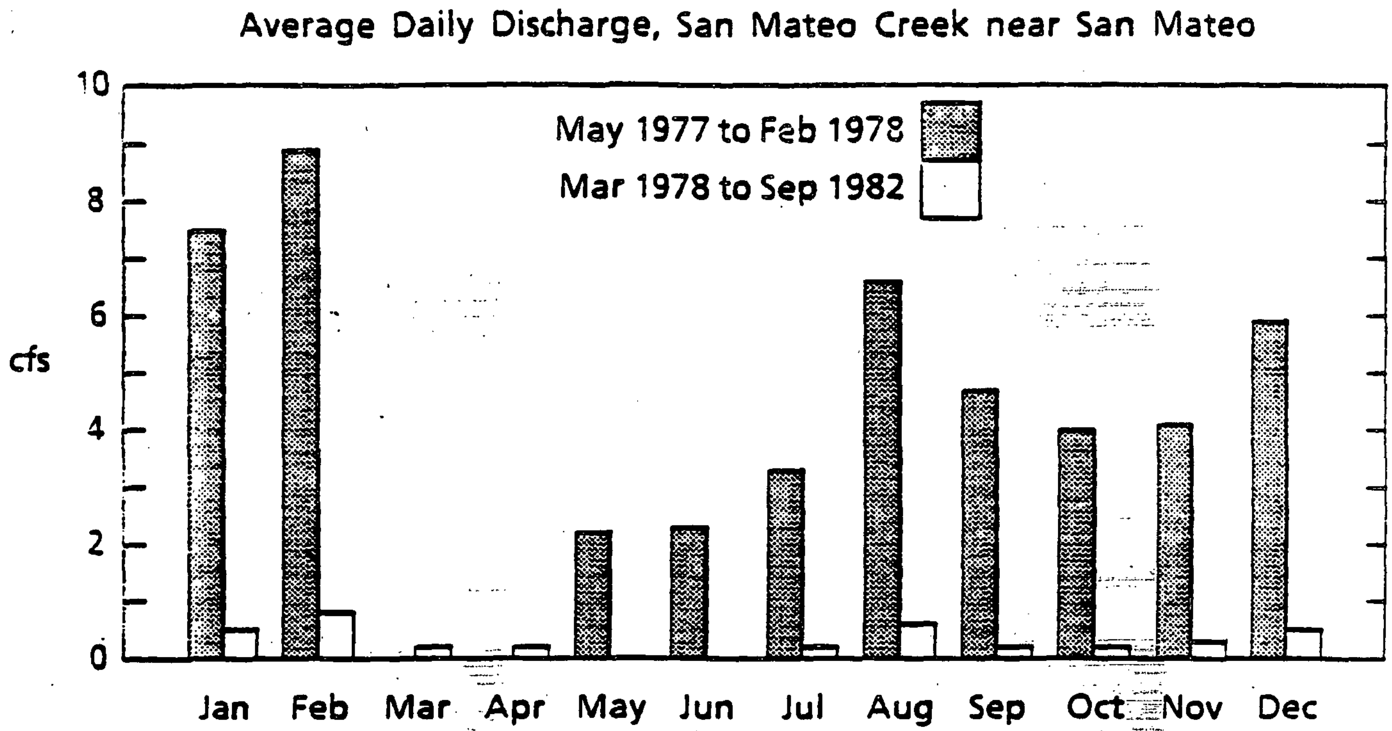


FIGURE 6.4 Average daily discharge for San Mateo Creek near San Mateo before and after diversion of mine dewatering effluents

1977 and May 1978. In the Ambrosia Lake mining district, infiltration was calculated at 7.54 m^3/min.

The overall hydrologic impact of mine dewatering on bedrock aquifers has been a region-wide acceleration of drawdown in these aquifers. In a limited number of stream reaches, however, the hydraulic connection between the alluvial aquifer and underlying bedrock allows some recharge of deeper sandstone aquifers (Lyford, 1979), i.e., water pumped from the mines is returned to the sandstone aquifers via recharge.

6.3.1. Hydraulic Connection Between Surface Waters and Shallow Ground Waters

While recharge generally is a continuous process along the minewater-dominated streams, it is intermittent under natural conditions. The intermittency of natural recharge largely minimizes the potential for dilution of contaminant concentrations in minewater affected ground water. Under natural conditions, ground-water levels most clearly demonstrate a response to surface flows in late winter and early spring. This period, usually February to April, is one of warming weather, melting snows, and gentle frontal rains. Stream flows during this period are usually increased above low winter flows. Moreover, these higher flows tend to be of long duration, often lasting several weeks. These flows, even though not of the magnitude of summer flash floods, provide a prolonged period of heightened flows that enhance infiltration to the underlying alluvium.

Figures 6.5 and 6.6 illustrate the intermittency of recharge from natural runoff along a reach of San Mateo Creek. In March and early April of 1980, a time when mine dewatering discharges to the channel were insignificant, occasional flows of less than 1 cfs, recharged the alluvium and caused the water table to rise slowly (Figure 6.5). In late April, however, stream flow increased to as great as 3 cfs. The period of increased flow was almost two weeks long, ending on April 29, 1980. Ground water response to the elevated flows was rapid: the water table began to rise within one week and peaked in mid-May, more than one foot higher than in mid-April.

In general, shallow ground water levels are much less responsive to summer flash floods. Such floods exhibit peak discharges often as great as several thousand cfs, but their potential for recharging ground water is offset by their brevity. The large volumes of thunderstorm runoff usually traverse miles of arroyo bed in a matter of hours. While most of the water eventually does infiltrate, it may penetrate only a short distance into the alluvium. Very little water reaches the water table; most is ultimately evaporated or transpired.

The relationship between surface flows and ground water levels in summer is illustrated in Figure 6.6. After receiving significant recharge in late April 1980, the alluvial aquifer underlying San Mateo Creek experienced a declining water table through the summer. Brief runoff events generated by thunderstorms during August had an insignificant impact on the declining levels. Even the high flows of September, which had an instantaneous peak discharge of 16 cfs (U.S. Geological Survey, 1980), failed to percolate to the underlying alluvial aquifer in noticeable quantities. While summer flash floods resulting from thunderstorms are probably too short-lived to significantly recharge alluvial aquifers, San Mateo Creek and other alluvial systems in the region do demonstrate a close hydraulic connection that is most responsive to late winter and spring stream flow.

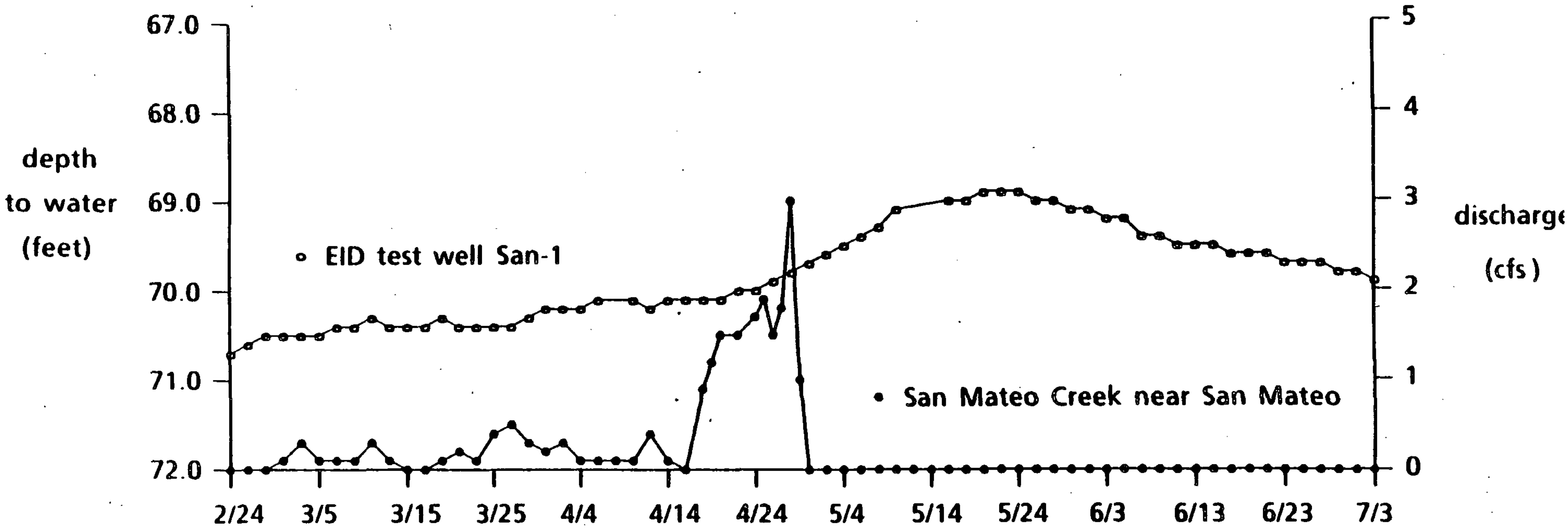


FIGURE 6.5 Streamflow and ground-water levels at the San Mateo Creek near San Mateo gaging site, February-July, 1980

6.3.2. Storage of Water in Alluvial Aquifers

Much of the water resulting from the dewatering of uranium mines has gone into storage in valley fill aquifers. Indeed, in the Ambrosia Lake district, water tables in affected aquifers may have risen as much as 50 feet between the onset of mine dewatering in the 1950s and the late 1970s (Kerr McGee Nuclear Corp.,1981).

Minewater production has been greatly reduced in the Ambrosia Lake district in recent years. Major minewater producers of the 1960s and 1970s (Kerr-McGee and Ranchers Exploration, for example) have drastically curtailed or completely ceased their discharges of dewatering effluents into San Mateo Creek and Arroyo del Puerto. Cessation of minewater discharges in this drainage basin has resulted in a diminished volume of water recharging the alluvium. Water levels in well OTE-1, below the confluence of Arroyo del Puerto and San Mateo Creek, showed continuous decline from March 1978 to March 1982 (Figure 6.7). During this time the water table at this site fell a total of eight feet, a rate of 2.0 feet per year. Alluvial water levels subsequent to the cessation of mine dewatering now appear to be returning to their natural conditions.

6.3.3. Bedrock Aquifers

For the most part, ground water recharge by dewatering effluents is limited to the shallow alluvial aquifers. There are a few stream reaches, however, in which the saturated valley fill overlies permeable bedrock with a downward hydraulic gradient. These places are recharge zones for northward dipping bedrock aquifers such as the Morrison Formation. At these localities, dewatering effluents are drawn by the downward gradients into the alluvium and eventually into the underlying sandstone.

Recharge of bedrock units by minewaters is seen to occur at varying degrees in virtually all of the mining districts where minewaters flow across bedrock subcrops or outcrops (Figure 6.8). This recharge mechanism has been noted in the Church Rock area by Raymondi and Conrad (1983) and Gallaher and Cary (1986); at Ambrosia Lake by Kaufmann, Eadie, and Russell (1976), Brod and Stone (1981), and Stephens (1983), and near San Mateo by Gulf Minerals Resource Co. (1979).

The total volume of minewater which enters the bedrock units probably represents only a small fraction of that which infiltrates to the shallow alluvial aquifers. Nevertheless, in the Ambrosia Lake district, effluents discharged to the Arroyo del Puerto and to the San Mateo Creek constitute a significant proportion of the locally derived recharge in the Dakota and Morrison Formations.

Recharge of the Morrison Formation by minewaters within the drainages is encouraged by regional dewatering of the unit by the mines. Despite some return flow of formation waters, local water level declines in excess of 500 feet have resulted from the dewatering (Lyford and others, 1980).

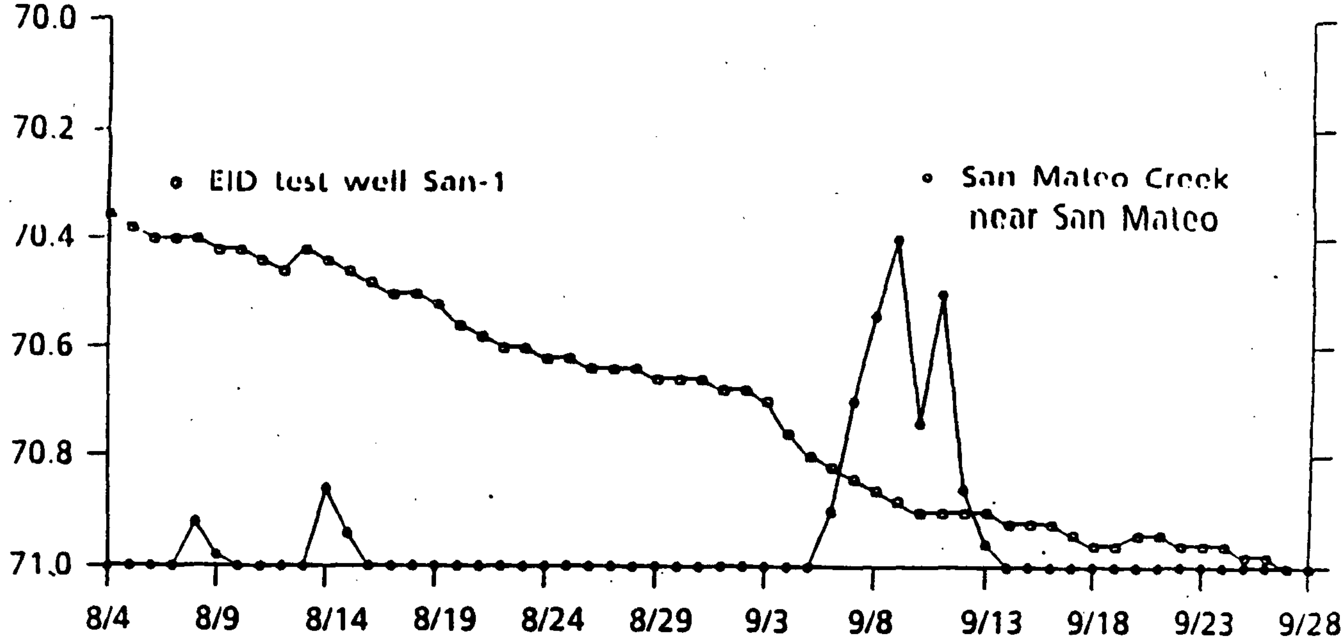


FIGURE 6.6 Streamflow and ground-water levels at the San Mateo Creek near San Mateo gaging site, August-September, 1980

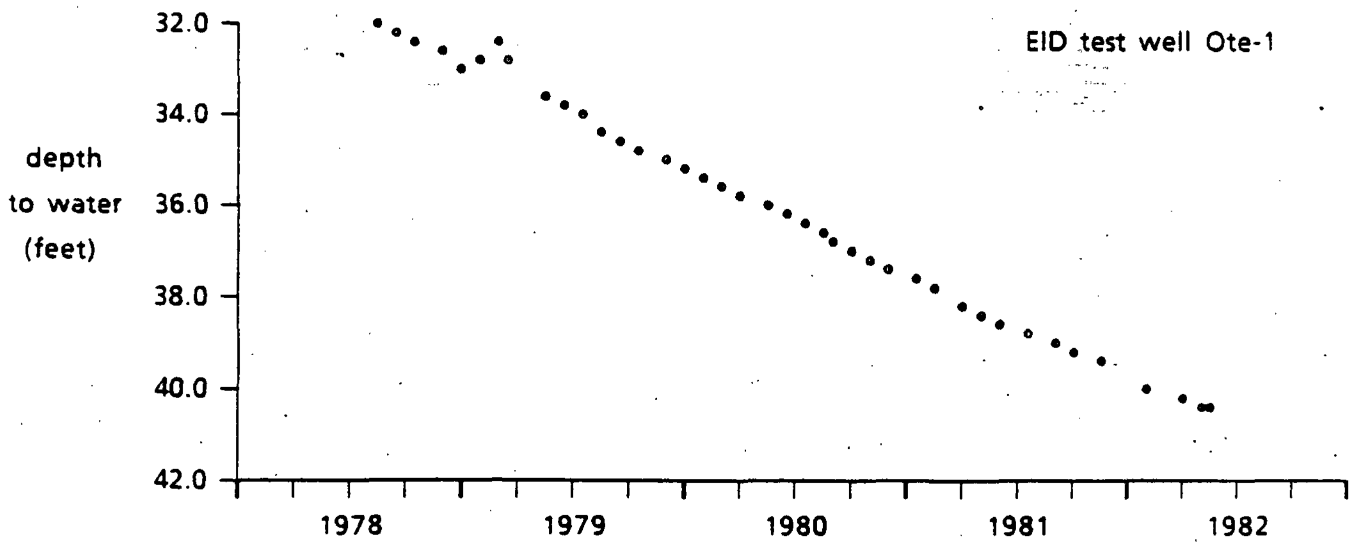


FIGURE 6.7 Ground water levels at EID test well OTE-1, 1978-1982

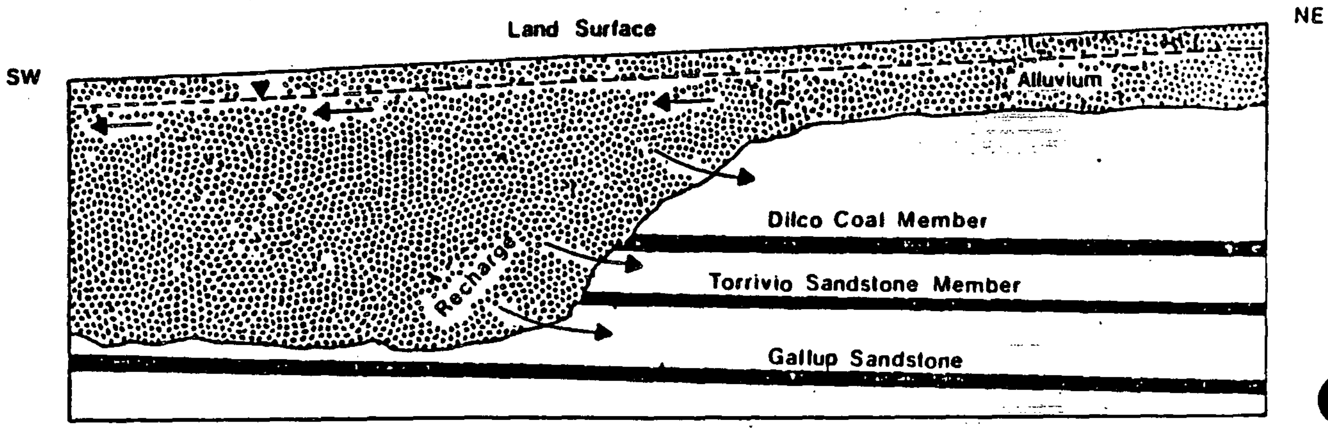


FIGURE 6.8 Conceptual diagram illustrating alluvial aquifer ground water recharge to underlying bedrock aquifers (after Raymondi and Conrad, 1983).

VII. IMPACTS OF MINE DEWATERING EFFLUENTS ON SURFACE WATER QUALITY

This chapter documents the chemical influences that mine dewatering effluents have had on the natural surface water environment. The chemical quality of treated minewaters differs in several important ways from the chemical quality of receiving surface waters. Dewatering effluents are most often different with respect to amounts of total dissolved solids and suspended sediments, general ionic composition, and concentrations of trace elements and radionuclides associated with uranium ore deposits.

In most affected drainages, dewatering effluents constitute a substantial portion of the total amount of water. Therefore, water quality characteristics of receiving streams frequently have been altered to reflect the chemical character of minewater rather than their natural quality. A comparison of the quality of effluent streams with regulatory standards is presented in Chapter IX.

7.1 RAW MINEWATERS

A review of the literature indicates that various trace elements, radionuclides, and dissolved salts can be found in raw (i.e. untreated) uranium mine dewatering effluents (Clark, 1974; U.S. EPA, 1975; Perkins and Goad, 1980). In raw minewaters in the Grants Mineral Belt (Table 7.1), the constituents present at elevated concentrations are 1) gross alpha and beta particle activities and the radionuclides radium-226, lead-210, and natural uranium; 2) the trace elements molybdenum and selenium and; 3) dissolved solids, particularly sulfate. Occasionally, barium, arsenic, and vanadium are detected at elevated concentrations in raw minewaters.

It was only in the past decade that mine dewatering effluents received any noteworthy treatment before their release into Grants Mineral Belt drainages. Until that time thousands of gallons per minute of raw minewaters were discharged to Arroyo del Puerto and the Puerco River. As suggested by Table 7.1, these waters often contained high levels of uranium, radium-226, and gross alpha particle activity.

7.2 TREATED MINEWATERS

Beginning in the mid-1970's, the quality of minewaters discharged to watercourses began to improve, because many mine operators adopted minewater treatment systems. The basic treatment strategy is outlined by Perkins and Goad (1980):

> Once the water pumped from a mine reaches the surface it usually goes through one or more mine water settling ponds. At most facilities a flocculant is added to promote settling. Barium chloride is usually added to the liquid after it has gone through one or more suspended solids settling ponds. Further settling and precipitation of radium as a barium sulfate salt then occurs as the liquid moves through additional settling pond(s). Where uranium levels are high enough to justify it, the liquid is usually run through an ion exchange (IX) plant for recovery of uranium contained in the mine water. The IX plant may either precede or follow barium chloride treatment.

As a result of treatment, minewater concentrations of radium-226, lead-210, polonium-210, natural uranium, and gross alpha activity are considerably reduced. Concentrations of most other minewater constituents, though, are not greatly influenced by these treatments. As

TABLE. 7.1. Quality of Raw Minewater at Active Mines, 1980 - 1982. All data reflect total concentration in grab samples collected by EID personnel.

CONSTITUENT	AMBROSIA LAKE MINING DISTRICT				CHURCH ROCK MINING DISTRICT			
	MAX.	MIN.	MEDIAN	SAMPLE SIZE	MAX.	MIN.	MEDIAN	SAMPLE SIZE
	(mg/l)							
TDS	1,800	740	1,235	10	960	434	525	9
SO_4	1,030	310	715	10	458	126	156	9
	(mg/l)							
As	0.08	0.008	0.021	8	0.40	0.005	0.008	6
Mo	5.30	<0.01	1.19	10	0.791	0.008	0.030	6
Se	1.22	0.014	0.075	10	0.071	0.011		6
U-natural	20.0	1.56	3.82	10	27.30	2.100	4.3460	6
	(pCi/l ± one sigma standard error of counting)							
Gross alpha	11,900 ± 1,400	490 ± 50	3,050 ± 300	14	24,000 ± 1000	460 ± 30	3,205 ± 150	10
Gross beta	6,550 ± 590	30 ± 16	280 ± 7	14	6,440 ± 550	530 ± 100	1,320 ± 200	6
Pb - 210	1,300 ± 100	15 ± 4	690 ± 52	4	1,200 ± 100	44 ± 4	--	2
Po - 210	14 ± 2	0.95 ± 0.35	4 ± 0.5	4	10 ± 1	3.4 ± 0.4	--	2
Ra - 226	1,650 ± 50	30 ± 9	280 ± 7	14	2,500 ± 800	7.0 ± 0.2	295 ± 5	10
Th - 228	0.6 ± 0.3	-0.1 ± 0.1	0.0 ± 0.1	5	0.1 ± 0.1	-0.2 ± 0.2	--	2
Th - 230	1,400 ± 100	0.2 ± 0.1	3.3 ± 0.5	5	210 ± 10	0.1 ± 0.1	--	2
Th - 232	4.0 ± 0.2	0.0 ± 0.1	0.0 ± 0.1	5	0.1 ± 0.1	0.0 ± 0.1	--	2

demonstrated in Table 7.2, a seven-fold reduction in average radium-226 and natural uranium concentrations in treated minewaters is found when 1975 data are compared with 1981-82 data.

TABLE 7.2 Comparison of 1975 Mine Dewatering Effluent Quality with 1981-82 Quality. Number of samples in parentheses.

Constituent	Flow-Weighted Means	
	1975*	1981-82**
Total Radium-226 (pCi/l)	71.2 (23)	10.5 (15)
Total Uranium-natural (mg/l)	7.25 (23)	1.0 (14)

* Calculated from data in U.S. EPA (1975).
** Calculated from data in EID files.

The quality of treated mine effluents during the period 1978 through 1982 is summarized for key constituents in Table 7.3. It is readily evident that substantial variability in water quality exists between the two major mining districts, as well as within each mining district. Most striking in this regard are the concentrations of total dissolved solids, sulfate, molybdenum, selenium, and radium-226.

The wide range in radium-226 concentrations reflects occasional poor operation of the radium treatment systems. Thomson and Matthews (1981) attribute these "upsets" to incomplete mixing of the mine waters with barium chloride and to poor settling of the barium-radium sulfate precipitates. Variability in molybdenum, selenium, sulfate, and total dissolved solids, on the other hand, cannot be attributed to ineffectual treatment. This variability instead reflects chemical differences in the ground waters discharged from the mines, as indicated in Table 7.1.

As would be expected, sludges which accumulate in the minewater treatment pond bottoms as a result of settling, floculation, and precipitation are highly concentrated in radium-226 and other radionuclides. Analyses presented by Perkins and Goad (1980) and additional data in EID files indicate that the radium-226 concentrations in the accumulated sludges probably average more than 200 pCi/gram. Under standards proposed by EPA (1976), uranium mine wastes with a radium-226 concentration in excess of 5 pCi/gram would be treated as hazardous materials and subject to special handling and disposal procedures.

7.3 EFFECTS OF MINE DEWATERING EFFLUENTS ON SURFACE-WATER QUALITY

The previous chapter discussed the significant effects that discharge of minewater effluents has had on the hydrology of watercourse in the Grants Mineral Belt. Effects on water quality have been similarly significant. This section discusses how the quality of these effluents differs from the quality of runoff that constitutes the natural water quality of the stream and how the quality of these artifically maintained streams changes as the waters flow downstream.

7.3.1. Comparison of the Quality of Mine Dewatering Effluents with Natural Runoff Quality

Under natural, pre-mining conditions, watercourses receiving mine dewatering effluents, such as San Mateo Creek and the Puerco River, often have low flows or are even dry. When flow occurs in these watercourses, it is the result either of storm runoff or of runoff from snow melt. Therefore, comparison of the quality of mine dewatering effluents with natural storm runoff

TABLE 7.3 Quality of Treated Minewater at Active Mines, 1977-1982. All data reflect total concentrations in grab samples collected by EID personnel. Number of samples in parentheses.

CONSTITUENT	AMBROSIA LAKE MINING DISTRICT				CHURCH ROCK MINING DISTRICT			
	MAX.	MIN.	MEDIAN	AVG.	MAX.	MIN.	MEDIAN	AVG.
	mg/l							
TDS	2,615	510	1,610	1440 (26)	1,190	360	452	580 (16)
SO_4	1,370	185	755	655 (22)	600	60	136	210 (17)
As	0.20	<0.005	0.011	0.02 (26)	0.02	<0.005	<0.005	0.007 (16)
Ba	1.7	0.1	0.21	0.24	2.1	0.10	0.413	0.5 (15)
Mo	3.2	0.03	0.80	1.0 (27)	0.6	0.01	0.01	0.2 (15)
Se	1.0	0.01	0.09	0.24 (27)	0.3	0.01	0.04	0.07 (15)
U natural	3.0	0.2	1.56	1.5 (26)	1.8	0.6	1.07	1.0 (14)
V	0.29	<0.01	0.029	0.08 (21)	0.07	0.01	0.012	0.02 (13)
	pCi/l ± SE*							
Gross alpha	1,760 ± 100	54 ± 14	635 ± 70	780 (14)	1,200 ± 100	280 ± 30	440 ± 40	600 (11)
Gross beta	945 ± 225	84 ± 16	377 ± 125	435 (6)	663 ± 125	322 ± 30	460 ± 74	480 (6)
Pb - 210	33 ± 6	6.9 ± 2.6	14 ± 5	15 (9)	10 ± 2	4.5 ± 2.3	--	-- (2)
Po - 210	14 ± 2	0.95 ± 0.35	1.1 ± 0.4	6 (4)	15 ± 5	3.4 ± 0.4	9.8 ± 7.4	10 (13)
Ra - 226	200 ± 10	0.12 ± 0.04	6.4 ± 1.2	27 (28)	89 ± 5	0.67 ± 0.2	2.0 ± 0.2	10 (13)
Ra - 228	0 ± 2	0 ± 2	0 ± 2	0 (5)	<0.2	<0.2	--	-- (2)
Th - 228	<0.3	<0.1	<0.1	0.2 (3)	0 ± 2	0 ± 2	--	-- (2)
Th - 230	4.0 ± 0.5	<0.3	0.7 ± 0.2	1.7 (3)	3.9 ± 0.5	<0.2	--	-- (2)
Th - 232	<0.1	<0.1	<0.1	<0.1 (3)	<0.2	<0.2	--	-- (2)

*SE = Standard Error of Measurement (one sigma) quality provides an indication of how the change from ephemeral to artificially-maintained perennial watercourses has affected chemical quality.

Suspended Sediment

In all effluent-dominated watercourses, suspended sediment concentrations under minewater baseflow conditions are smaller than the concentrations borne by thunderstorm runoff (see Chapter IV). EID and uranium industry self-monitoring data indicate that these simple treatment measures, used to remove radium-226 before discharge to watercourses usually reduce suspended sediment concentrations from more than 100 mg/l in the untreated minewater to less than 10 mg/l in the final effluent. Runoff has average suspended sediment concentrations greater than 30,000 mg/l.

Although treated minewaters are relatively free of sediment when they are discharged, they eventually become burdened with suspended silts and clays. Stream channels in the Grants Mineral Belt which receive mine dewatering effluents are relatively free of suspended sediments just below the point of minewater discharge. Silt and clay particles are entrained from the channel bed as flow continues downstream. On November 13, 1980, for example, suspended sediment concentration increased from 52 mg/l below the Kerr-McGee Church Rock I mine outfall in Pipeline Arroyo to 3500 mg/l in the Puerco River in Gallup approximately 19 miles downstream. Similar trends were evident on other days as well.

San Mateo Creek in the Ambrosia Lake district also entrains sediment. The prevalence of sand over fine-grained sediments in the San Mateo Creek alluvium, however, causes suspended sediment concentrations, typically less than 400 mg/l, to be lower than in the Puerco River system.

Dissolved Solids

Concentrations of total dissolved solids (TDS) in minewaters are variable in the Grants Mineral Belt. In the western portions of the Ambrosia Lake mining district, mines produce waters with 1200 to 1800 mg/l TDS (Perkins and Goad, 1980). These concentrations are reflected in Arroyo del Puerto, where TDS concentrations are often 1500 to 2,000 mg/l. Mixing of mine dewatering effluents with natural waters resulting from runoff occasionally dilutes TDS levels in this watercourse to less than 1,000 mg/l. Minewaters discharged to Arroyo del Puerto thus bear about twice the concentration of dissolved solids of that in natural runoff in the area, which is typically below 1,000 mg/l TDS.

In contrast, minewaters produced in the Church Rock and the eastern portion of the Ambrosia Lake districts usually contain only a few hundred mg/l TDS. Data presented by Perkins and Goad (1980) demonstrate that effluents discharged to Pipeline Canyon and San Mateo Creek contain only 300 to 600 mg/l TDS. TDS values in natural runoff are quite similar. In the these areas, therefore, minewaters have not influenced the TDS concentrations of receiving streams. It is noteworthy that the TDS concentrations are only one-fourth of those found in western portion of the Ambrosia Lake minewaters despite the fact that all minewaters are produced largely from the Morrison Formation. High TDS concentrations in the western portion of the Ambrosia Lake district have been attributed to greater mineralization of the host rock and to dewatering-induced leakage of more saline ground water into the mines from the overlying Dakota Formation (Brod, 1979; Kelley and others, 1980).

The relative concentrations of specific ions in minewaters appear to differ from concentrations found in natural runoff. Analysis of Figures 7.1 and 7.2 indicates that minewaters generally have proportionally more sodium and sulfate than natural runoff.

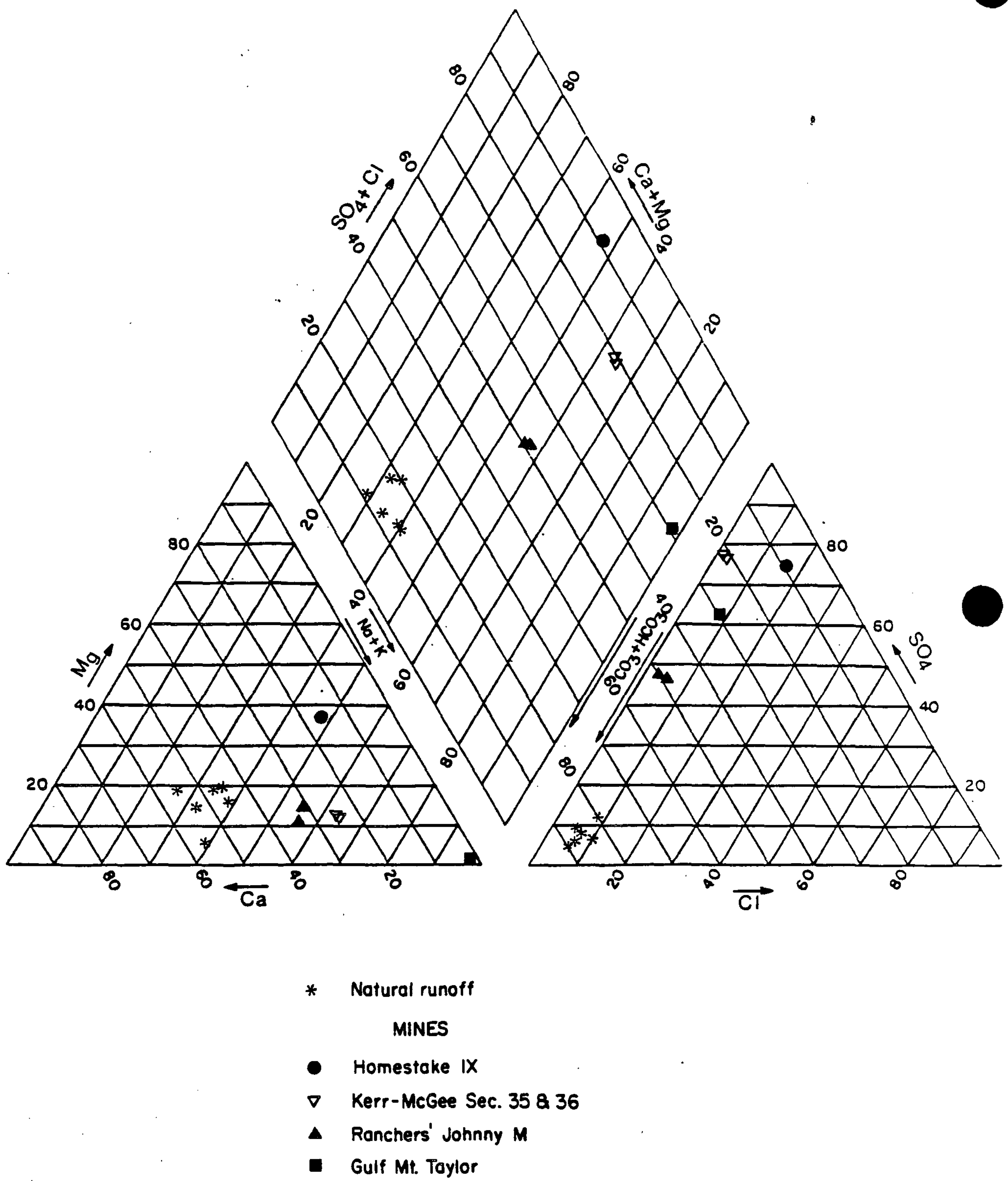


FIGURE 7.1 Comparison of the ionic composition of mine dewatering effluents and natural runoff, Ambrosia Lake mining district. Ions are expressed as percentage of total equivalents per liter.

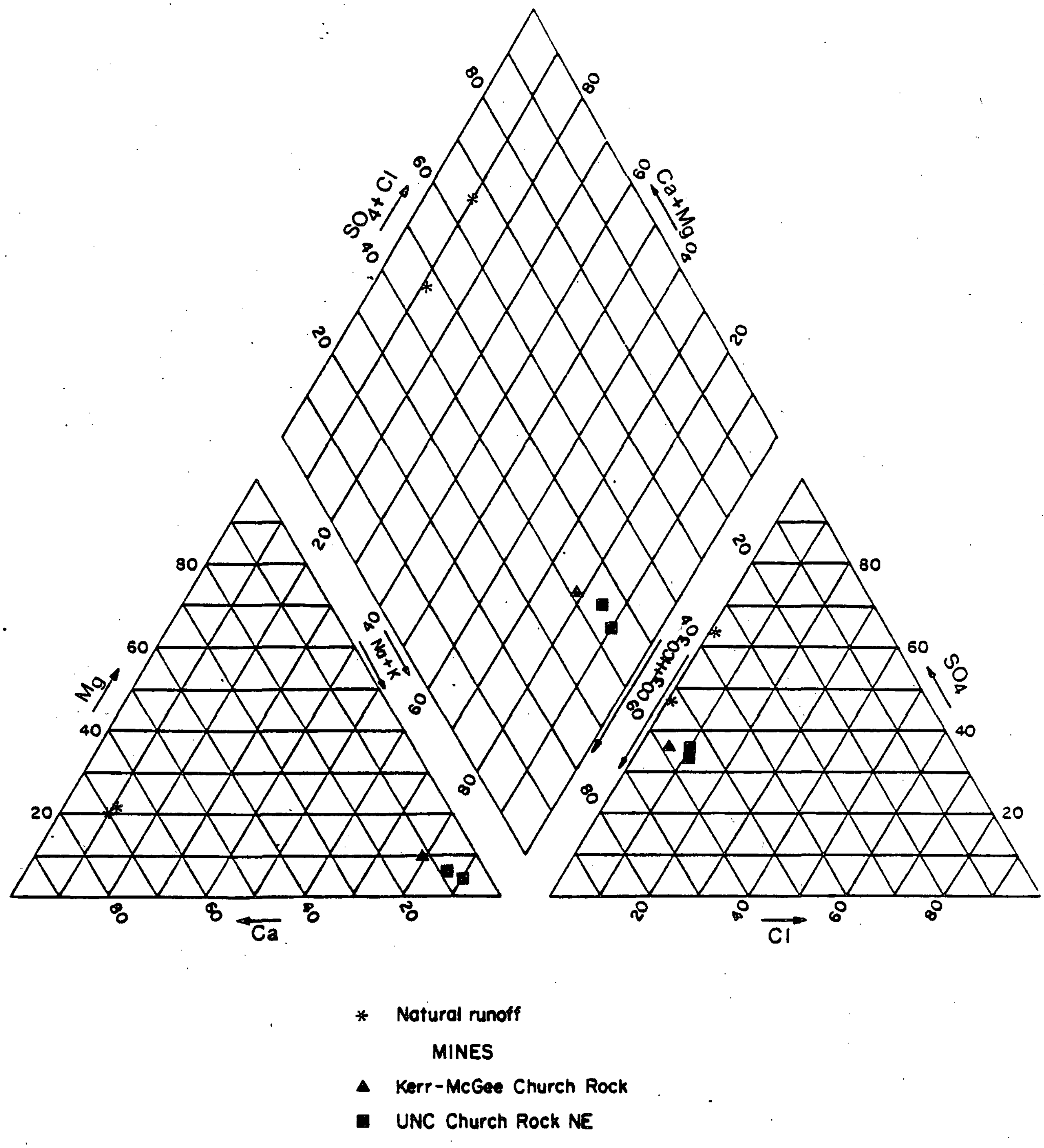


FIGURE 7.2 Comparison of the ionic composition of mine dewatering effluents and natural runoff, Church Rock mining district. Ions are expressed as percentage of total equivalents per liter.

Total versus Dissolved Concentrations

In contrast to natural runoff in which contaminants are largely associated with suspended sediment and precipitates, trace elements and radionuclides in treated minewaters are generally present in the dissolved form. The proportions of minewater contaminants in the dissolved phase are highly variable, but typically the dissolved fraction of a contaminant constitutes more than 50 percent of the total concentration (Table 7.4). Usually, more than 85 percent of the total concentration of gross alpha activity, molybdenum, selenium, and natural uranium in minewaters is in the dissolved fraction. Dissolved radium-226 proportions average about 30 percent of the total concentration.

The following discussion of trace elements and radionuclides focuses on comparison of total constituent concentrations in treated minewaters with total concentrations in natural runoff. Direct comparisons of dissolved concentrations are limited by the amount of available data. Nonetheless, based on information in Table 7.4, it can be assumed for many contaminants that even if minewaters and runoff have nearly equivalent total contaminant concentrations, then the dissolved concentrations in minewaters are probably significantly greater than in natural runoff, particularly for gross alpha particle activity, molybdenum, selenium, and natural uranium.

Trace Elements

Of the nine trace elements routinely analyzed in treated minewaters, only the concentrations of molybdenum, selenium, and uranium are consistently higher than in natural runoff (Figure 7.[illegible] Since these trace elements are known to be naturally associated with uranium ores, their presence in surface watercourses suggests that the watercourse is receiving mine dewatering effluents. Arsenic, vanadium, and barium are occasionally detected in significant concentrations in minewaters, the latter because it is added in the treatment process to remove radium-226. Cadmium, lead, and zinc are usually below detectable levels in dewatering effluents and are therefore judged not to be of concern in these waters.

Uranium is the trace element with the highest concentrations in mine effluents throughout the Grants Mineral Belt. The median concentrations of total uranium in Ambrosia Lake and Church Rock effluents of 1.6 and 1.1 mg/l, respectively, are over 16 and 37 times greater than the median concentrations of natural runoff in the districts.

Molybdenum levels in minewaters vary from extremely low levels to more than 3 mg/l. Discharges in the Ambrosia Lake district have median total molybdenum concentrations of 0.80 mg/l. In comparison, only a small fraction of the natural runoff samples collected during this study contained detectable concentrations (> 0.01 mg/l) of total molybdenum. Lower concentrations are found in the Church Rock district, where the median total molybdenum concentration in effluents is 0.01 mg/l.

The third element that is consistently higher in mine dewatering effluents than in natural runoff is selenium. Treated effluent normally contains less than 0.04 to 0.09 mg/l selenium, but a few Ambrosia Lake mines discharge effluent with selenium concentrations approaching 1.0 mg/l. In contrast, data indicate median total selenium levels in natural runoff of 0.03 mg/l in Ambrosia Lake district and <0.005 mg/l in the Church Rock district.

Two other metals that occasionally appear in dewatering effluents are arsenic and vanadium. Elevated levels of arsenic and vanadium appear to be restricted to one facility in the region. The discharge from the Homestake ion exchange facility in Ambrosia Lake contains average total arsenic and vanadium concentrations of 0.05 and 0.17 mg/l, respectively.

TABLE 7.4 Percentage of Total Constituent Concentrations in the Dissolved Phase of Treated Minewaters, Ambrosia Lake and Church Rock Mining Districts, 1980.

CONSTITUENT	NO. OF SAMPLES	PERCENT IN DISSOLVED PHASE	
		RANGE	MEAN
As	3	12 - 90	57
Ba	5	<35 - 100	<71
Mo	6	88 - 100	95
Se	5	83 - 100	93
U-natural	5	68 - 100	89
V	5	20 - 100	61
Gross alpha	6	82 - 100	94
Gross beta	5	72 - 100	93
Ra-226	6	2 - 71	32

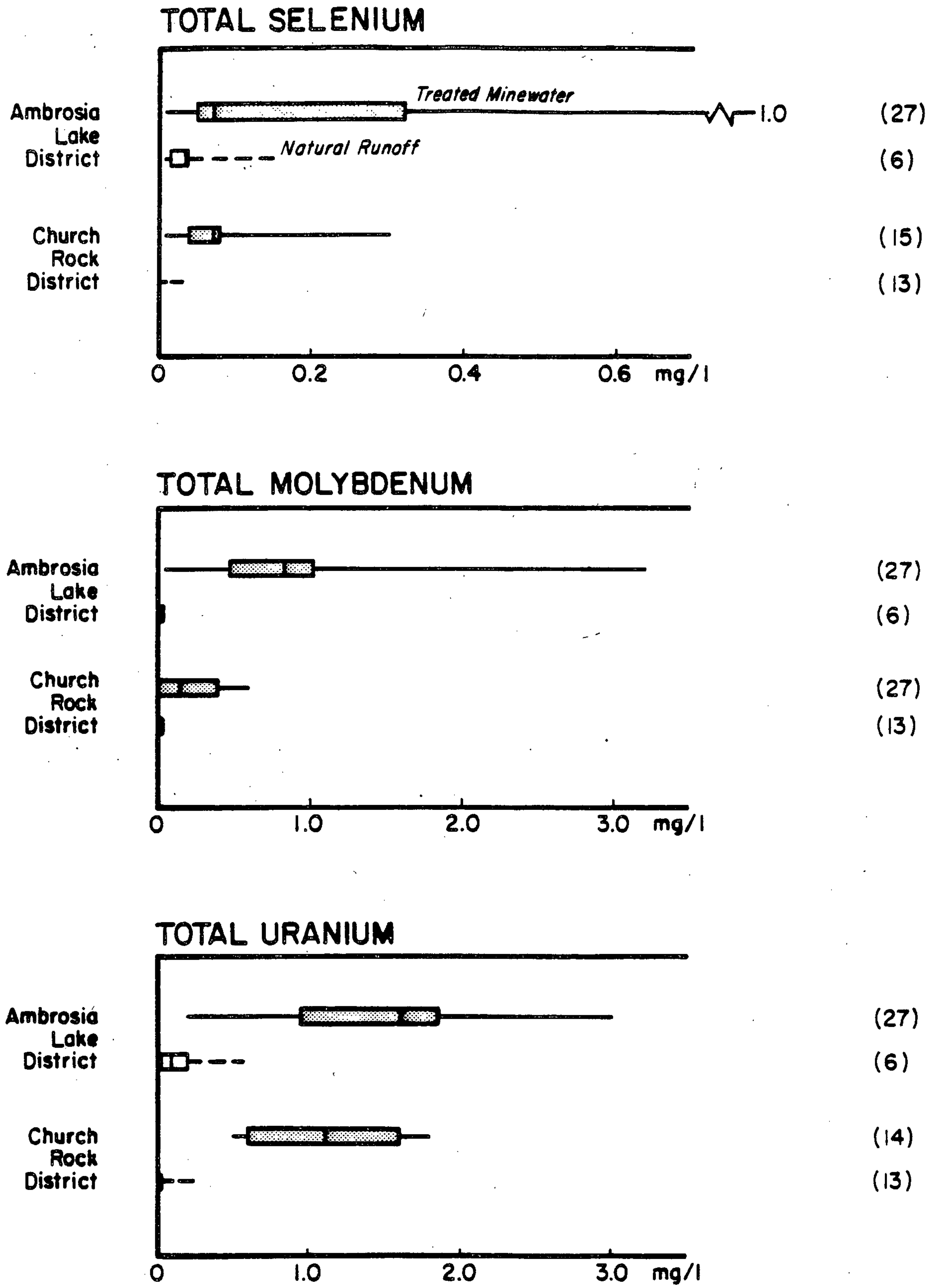


FIGURE 7.3 Comparison of selected total trace element concentrations in treated minewaters and natural runoff

Barium is of potential interest because it is added as barium chloride to co-precipitate radium-226 from minewaters before their discharge to watercourses. Median total barium concentrations in natural runoff in Ambrosia Lake and Church Rock districts are 7.7 and 4.8 mg/l, respectively. These are many times greater than the concentrations of 0.212 and 0.413 in treated minewaters from these districts.

Radionuclides

With the exception discussed above of natural uranium, median total concentrations of radionuclides in treated minewaters are less than those measured for natural runoff (Figure 7.4). Compared to natural runoff, however, minewaters have a higher, usually considerably higher, percentage of total radionuclide concentrations associated with the dissolved phase. EID data indicate that as much as 99 percent of the gross alpha and gross beta particle activities of natural runoff are associated with precipitates and suspended sediment. In contrast, over 90 percent of this radioactivity in treated minewaters is normally associated with the dissolved fraction (see Table 7.4). Total suspended sediments in dewatering effluents are quite low (averaging about 5 mg/l).

The total gross alpha particle activity of dewatering effluents is comparable to natural runoff levels. Dissolved gross alpha levels of several hundred to over 1,000 pCi/l in dewatering effluents, on the other hand, are ten to one hundred times greater than dissolved gross alpha levels in natural runoff (normally less than 20 pCi/l). On average, dissolved uranium accounts for more than 80 percent of the observed total gross alpha activity. Other alpha-emitters in the uranium-238 decay series (chiefly, thorium-230, radium-226, and polonium-210) are present in small concentrations in the effluents relative to uranium (see Table 7.3).

Median total gross alpha and beta concentrations are roughly equivalent in Ambrosia Lake and Church Rock mine effluents. Maximum concentrations of these constituents in Ambrosia Lake discharges, though, are about 40 percent greater than in the Church Rock discharges. The differences are most likely due to more effective ion-exchange treatment of the minewaters in the Church Rock district.

Despite high concentrations of radium-226 in raw minewaters, most mines discharge minewaters with 6 pCi/l or less of total radium-226 (Figure 7.4). While an average of about 30 percent of the radium in these effluents may be in the dissolved form, natural runoff often exceeds 15 pCi/l in total radium-226, but is quite low in dissolved radium-226, usually less than 2 pCi/l. Three facilities, evidently sampled during "upset" conditions, discharged effluent containing 75, 89, and 200 pCi/l total radium-226, concentrations similar to concentrations in untreated minewater. Large influxes of dissolved radium-226 may be introduced to receiving watercourses from any mine with ineffective radium-removal processes.

None of the thorium isotopes or radium-228 are normally present in detectable levels in minewaters. Treated minewaters have exhibited up to 33 pCi/l of total lead-210 and up to 15 pCi/l of total polonium-210. Greater concentrations (several hundred pCi/l) may ocur during periods of ineffective minewater treatment. Although the data are limited, there does not appear to be significant differences between the Ambrosia Lake concentrations and those presented for the Church Rock district. Natural runoff, in comparison, typically contains between 40 to 90 pCi/l each of total lead-210 and polonium-210.

7.3.2. Fates of Minewater Constituents in Surface Drainage Channels

Of the trace elements and radionuclides identified earlier as being elevated above levels in natural runoff, only radium-226 and lead-210 are known to undergo significant partitioning

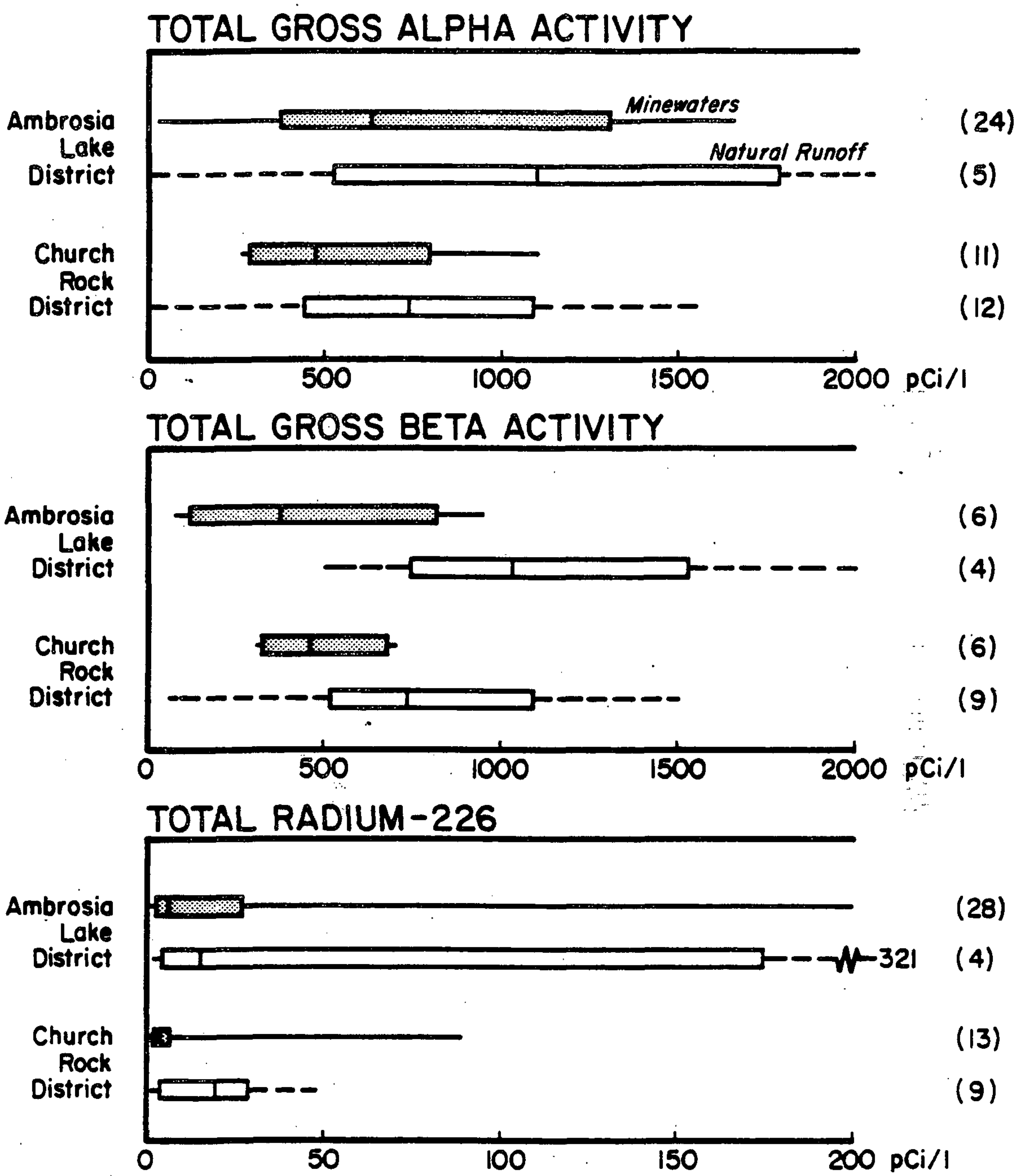


FIGURE 7.4 Comparison of total radioactivity in mine dewatering effluents and natural runoff

changes between dissolved and suspended phases as they travel downstream. These radionuclides are usually lost from solution shortly after their release to regional arroyos. Investigation of both dissolved and suspended phases revealed that precipitates and sediments suspended in the water account for virtually all these constituents. As shown in Table 7.5, a significant proportion of radium-226 is discharged to the Puerco River in dissolved form, but by the time radium-226 has travelled a few miles almost none remain in solution.

Once precipitated or bound to the stream sediments, minewater contaminants are subject to being moved downstream during normal artificially-maintained flows or, more significantly, during natural runoff events. During major streamflows, minewater-affected sediments are scoured from the stream bottoms, mixed with other sediments carried by the streamflows, and redeposited variable distances downstream. In drainages with sediment-rich streamflows, minewater-affected sediments generally become indistinguishable from other sediments carried along the watercourse and deposited on the stream bottom due to the large dilution factors involved and to the elevated levels of natural radioactivity in regional soils. Popp and others (1983) confirmed this along various drainages within the Rio Puerco watershed.

While dissolved radium-226 and lead-210 usually precipitate or are adsorbed by stream sediments, these radionuclides appear to stay in solution in stream channels that are relatively sediment free. Dissolved radium-226 concentrations along the Arroyo del Puerto, for example, consistently range between 3 and 6 pCi/l.

Unlike radium-226 and lead-210, the trace elements uranium, molybdenum, and selenium, and the major dissolved solids generally are not rapidly attenuated in the channels of receiving waters. These constituents generally remain in solution and move downstream with the minewater. Figure 7.5 shows downstream changes in water quality along the Puerco River on October 6, 1976 as an example (U.S. Geological Survey, 1977). The data show that constituents not precipitating or interacting rapidly with sediment decline gradually in concentration downstream, but still may be found in significant levels 50 miles from the mines. The declines in selenium and gross alpha concentrations are most likely related to decreasing pH levels downstream. While the initial dissolved radium-226 concentration is significantly elevated in contrast with the radium-226 levels measured during this study, concentrations nevertheless decline rapidly downstream. Similar responses have been found by the U.S. Geological Survey and the EID at more typical concentrations.

Table 7.5 Comparison of dissolved versus suspended concentrations of radium-226 at sites along the Puerco River. Data represent average concentrations. Number of samples in parentheses.

Site	Dissolved Ra-226 (pCi/l)	Total Ra-226 (pCi/l)	Suspended* Ra-226 (pCi/l)	River Miles From Mines
Church Rock Mines	3.2**(13)	9.98(13)	6.78	----
Puerco R. at NM 566	0.22 (14)	8.06 (13)	7.84	5.1
Puerco R. at Gallup	0.11 (12)	7.93 (12)	7.82	18.5

*Determined by subtraction.
**Estimate based on data in Table 7.4.

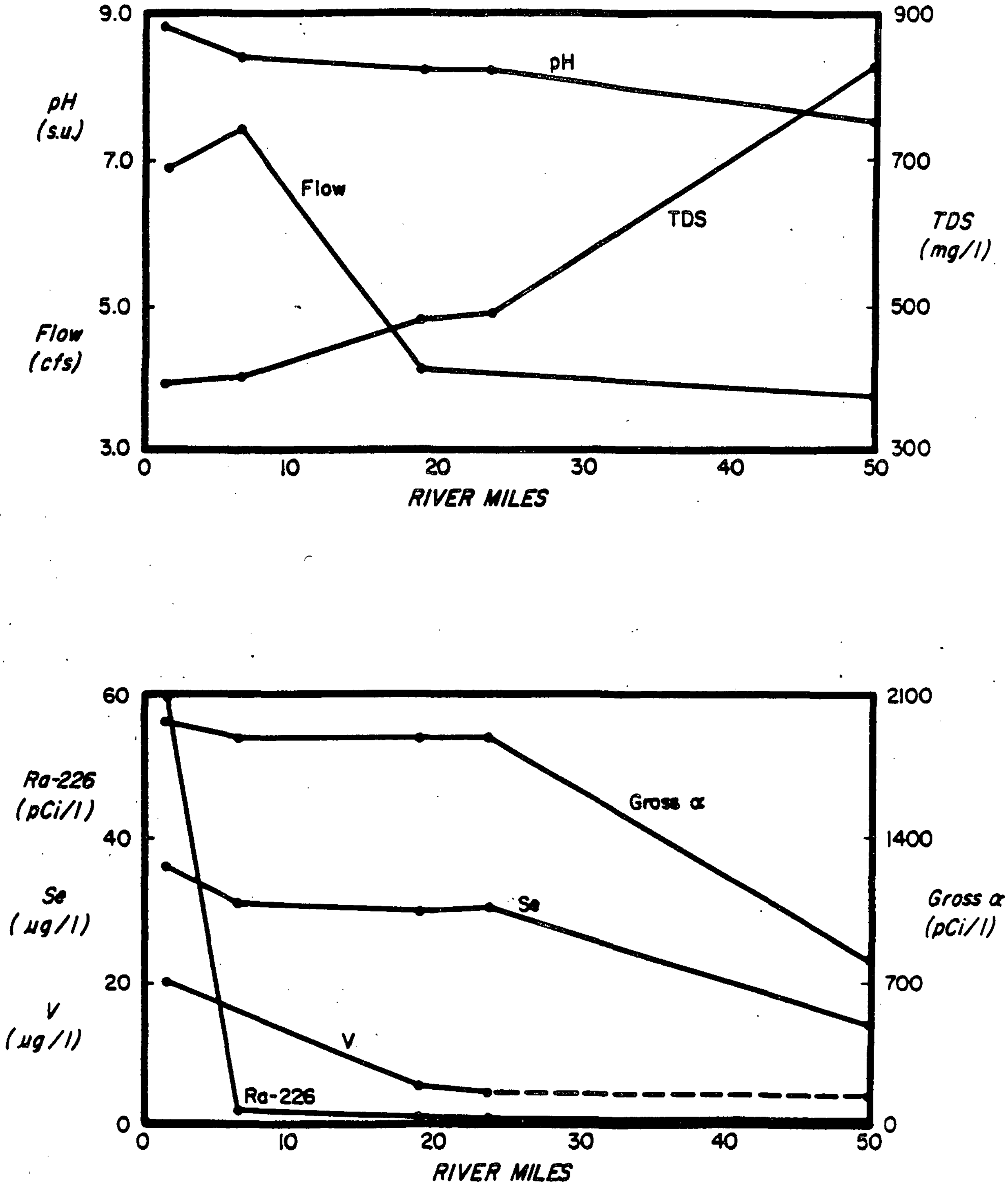


FIGURE 7.5 Water quality and flow along the Puerco River from the Church Rock mines to the New Mexico-Arizona border, October 6, 1976 (source: U.S. Geological Survey).

VIII. MINEWATER IMPACTS ON THE QUALITY OF SHALLOW GROUND WATERS

Release of dewatering effluents to Grants Mineral Belt arroyos greatly increased the volume of water infiltrating to shallow alluvial aquifers. This infiltration has been accompanied by a gradual change in the overall chemistry of these ground waters. In certain locations along San Mateo Creek and the Puerco River, the alluvial ground waters now bear a stronger chemical resemblance to minewaters than to natural waters. This condition is most pronounced in areas where stream-bottom leakage is high. Evaluation of this apparent change is somewhat hampered, however, by the lack of pre-mining ground water quality data.

Many of the impacts realized by surface waters are not experienced by underlying ground waters. Minewater constituents that adsorb to sediments or form insoluble precipitates do not usually reach ground waters. Chief among such constituents is radium-226. As shown previously, radium-226 quickly leaves solution in most Grants Mineral Belt streams, either by adsorbing to sediments or by forming insoluble precipitates, and thus is not found in significant concentration in alluvial ground water. On the other hand, chemical constituents that do not readily interact with earth materials or form insoluble precipitates, such as uranium, selenium or molybdenum, may be found in ground waters in concentrations approaching those in undiluted minewater and suggest ground water degradation from mine dewatering effluents.

Within the drainages studied effluent-dominated surface flows more closely approximate the infiltration capacity of the stream channel bottoms than those associated with natural runoff. The factor that most controls recharge volumes at any given location within these drainages, therefore, is duration of surface flow rather than flow rate or volume. Because of their perennial nature, effluents potentially may affect ground-water quality to a greater extent than would be projected from a comparison of volume of effluent-to-volume of natural runoff.

Variation of effluent seepage will cause fluctuations in ground water quality in the alluvium. For example, during spring runoff more dilution (mixing) of effluent with surface water takes place. This commingled water then may gradually with ground water in the alluvium. Under this condition, ground water quality is probably only locally affected. Conversely, under low-flow conditions and with the same amount of effluent discharged, ground water contamination may become more significant. Factors contributing to degradation of ground water quality include effluent quality and quantity, the amount of mixing of surface and ground water, permeability of the aquifer, surface and ground water quality, dispersion, advection, and the biological and geochemical processes taking place in the subsurface.

8.1 ESTIMATION OF NATURAL GROUND-WATER QUALITY

While the available data are limited, natural, alluvial ground-water quality can be generally described for some constituents. Pre-mining analyses in the Ambrosia Lake and Church Rock mining districts are limited in quantity and scope. Due to the rural nature of San Mateo Creek and the North Fork of the Puerco River, minimal testing of wells was performed before 1974. Most of the pre-mining data are limited to one-time samplings of a few isolated windmills for general chemical characteristics, e.g., sulfate and total dissolved solids, and there are no pre-mining trace element or radionuclide data available for either drainage. The following analysis of natural ground water quality in these drainages uses pre-mining data from stock wells 16-K-336 and 16-K-340 located along the

Puerco River 8.1?

San Mateo Creek (Figure 8.2). There are no pre-mining data available for alluvial waters along the Arroyo del Puerto.

The most useful information for describing natural alluvial ground-water quality comes from wells drilled for and sampled during this assessment. In particular, data obtained from wells located upstream of uranium industry activities reflect the equivalent of pre-mining conditions at those locations. These wells include the BLM wells along the Puerco River (Figure 8.1) and the Lee wells along the San Mateo Creek in the Ambrosia Lake district in the Church Rock district (Figure 8.2)

8.1.1. General Chemistry

Superimposed on any local variabilities in alluvial ground water quality along the North Fork of the Puerco River are regional-scale quality changes. The available records suggest that natural alluvial ground water trends from a calcium sulfate water at the BLM cluster near Pinedale Bridge to a sodium sulfate water at well 16-K-340, and subsequently to a sodium bicarbonate water near Church Rock at well 16-K-336. The ionic composition are presented in Figure 8.3. The calcium-rich water is reflective of gypsum ($CaSO_4$) and lime ($CaOH$) abundant in the soils near Pinedale. The proportion of sodium increases downstream after soils derived from rocks of Jurassic age are encountered (see Figure 2.5). All of these regional changes appear to be gradual trends in response to changes in the parent rocks.

Along the North Fork of the Puerco River, water quality is highly variable with respect to total dissolved solids (TDS) concentrations. TDS concentrations range from less than 200 to over 1500 mg/l and generally increase with increasing distance from the river channel. The relative proportions of principal cations and anions, however, do not appear to change appreciably with increasing distance from the channel.

Natural alluvial ground waters along the San Mateo Creek trend from a sodium bicarbonate water at the Lee wells to a sodium-sulfate-bicarbonate water at the Sandoval Ranch (Figure 8.4). The bicarbonate is reflective of limestone rocks near the village of San Mateo.

Natural TDS concentrations in San Mateo Creek ground waters range from 500 to 1,000 mg/l (Brod and Stone, 1981). Along the six-mile distance from the Lee wells near San Mateo downstream to the Sandoval Ranch windmill, TDS concentrations do not significantly change; the increase is from 540 to 650 mg/l.

There are no data to describe natural TDS concentrations downstream for the Sandoval Ranch, but concentrations are not expected to increase dramatically in the three-mile distance to the Otero well cluster location (see Figure 8.2). While San Mateo Creek alluvial waters downstream of the Sandoval Ranch could be affected by the inflow of Arroyo del Puerto alluvial ground waters, available data suggest that there was minimal alluvial water along the Arroyo del Puerto under pre-mining conditions (Kerr-McGee Nuclear Corp., 1981).

8.1.2. Molybdenum

Under natural conditions concentrations of molybdenum in alluvial ground waters along the North Fork of the Puerco River and San Mateo Creek are expected to be low. Molybdenum concentrations in ground waters produced from all BLM and Lee wells are very low, consistently less than detection limit of 0.010 mg/l. While there are no other ground water data available for estimating natural molybdenum concentrations, analyses

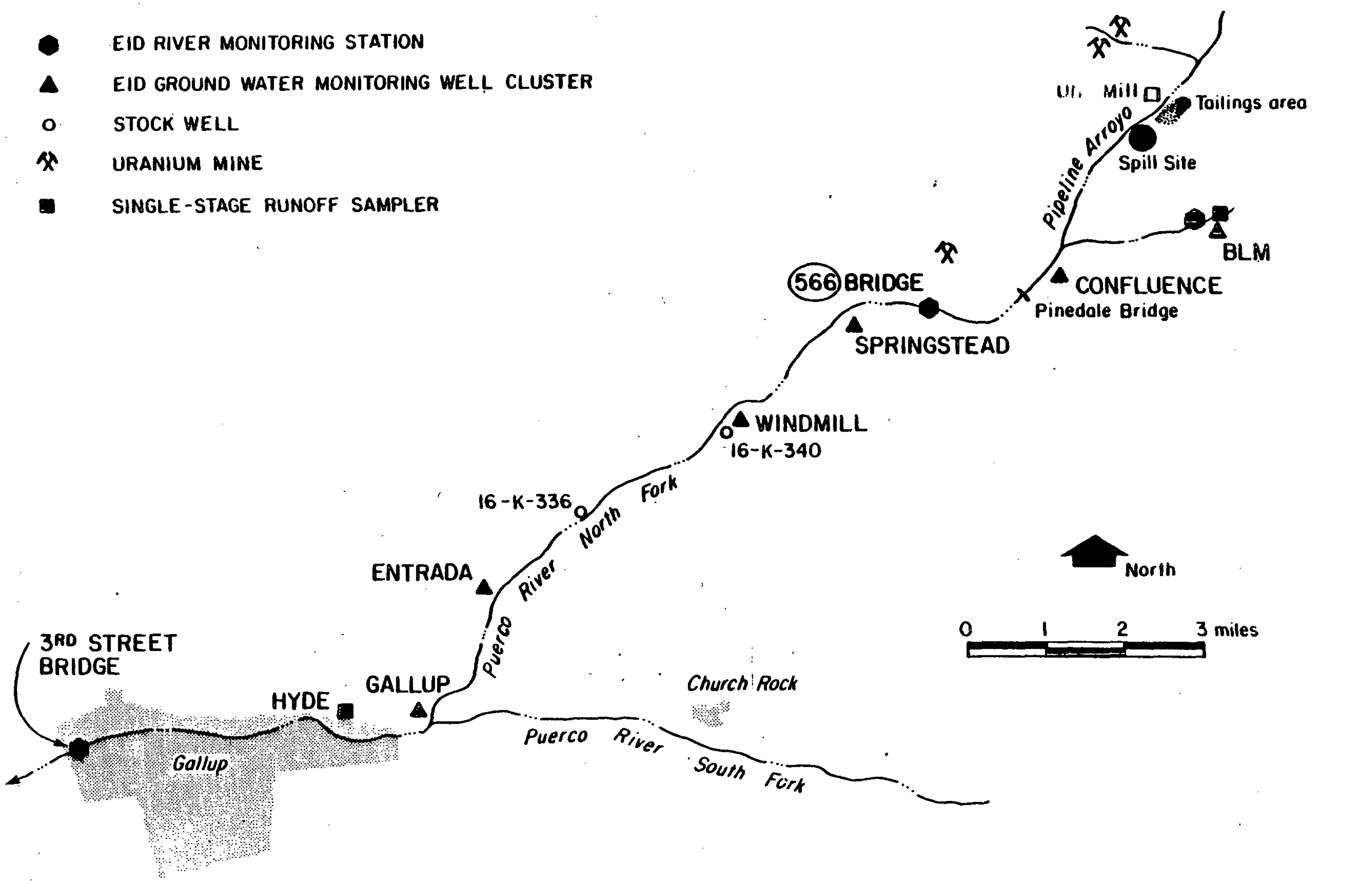


FIGURE 8.1 Well locations in the Church Rock mining district and along the Puerco River

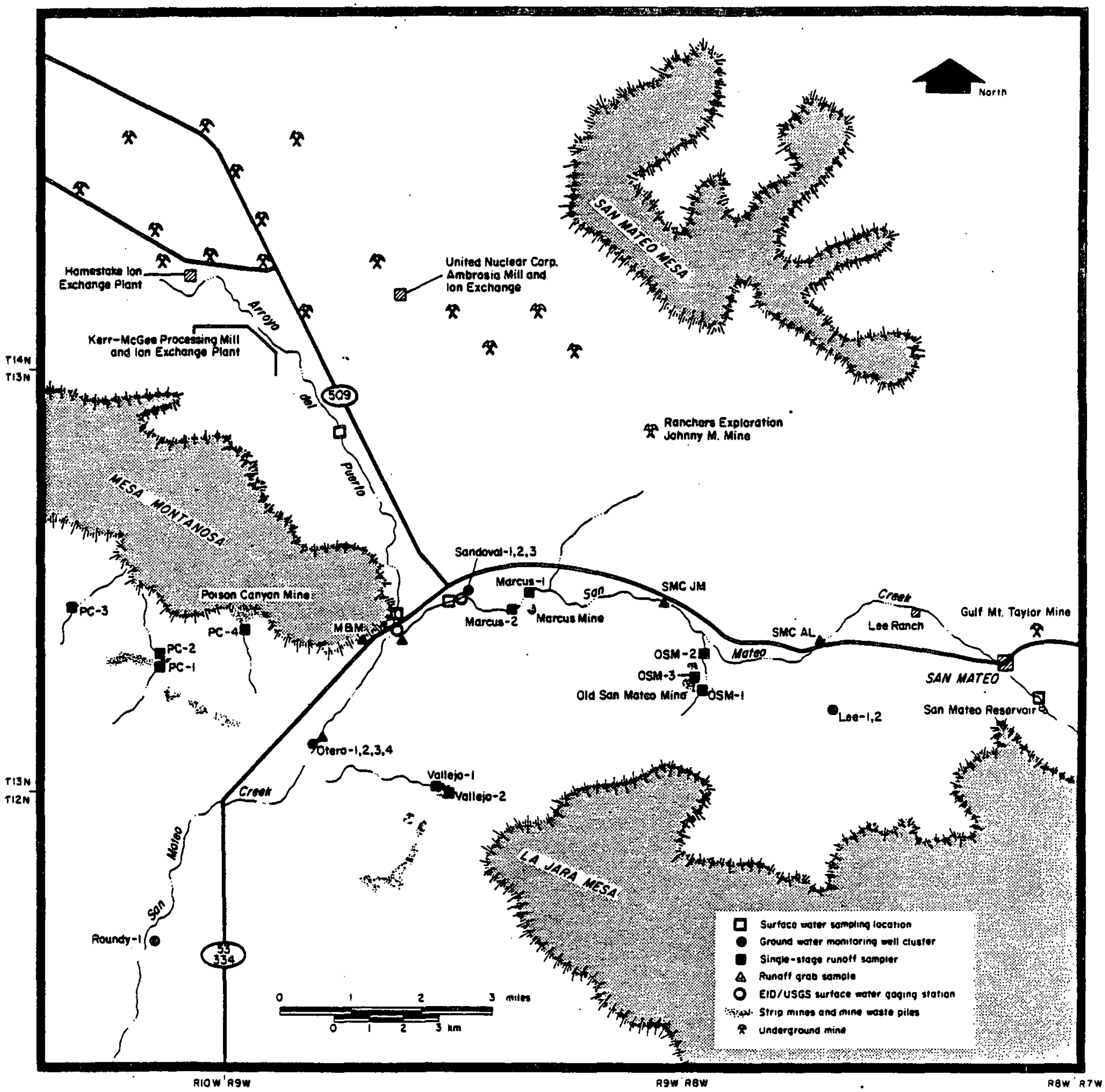


FIGURE 8.2 Well locations in the Ambrosia Lake mining district

of unfiltered natural runoff indicate the virtual absence of molybdenum in sediments and natural waters in these drainages (see Table 4.3).

8.1.3. Uranium-natural

Statistical analyses have been performed on data from the North Fork of the Puerco River in attempt to estimate naturally occurring uranium concentrations in alluvial ground waters within that drainage (see Sinclair Probability Plots, section 3.4.1). These analyses allow differientation of natural ground waters from those influenced by uranium industry wastewaters (i.e., minewaters and the United Nuclear Corporation uranium mill tailings spill). Details of these analyses are given fully elsewhere (Gallaher and Cary, 1986) and are only summarized here.

Results of the analyses suggest that natural uranium concentrations for the North Fork of the Puerco River average approximately 0.02 mg/l and rarely exceed 0.06 mg/l. The estimated average natural concentration is identical to that suggested by U.S. EPA (1975). Average uranium concentrations at the BLM cluster range from 0.014 to 0.048 mg/l.

Natural uranium concentrations in alluvial waters along San Mateo Creek potentially may be higher than along the Puerco River. The abundant natural uranium ore outcrops in the San Mateo Creek drainage (for example, at Marcus and Poison Canyon mines; see Figure 8.2) probably contribute sediments enriched in uranium to the alluvium and these, in turn, contribute uranium to ground waters flowing in the alluvium. That natural runoff in the Ambrosia Lake mining district typically contains total uranium concentrations about three times higher than in the Church Rock mining district is indirect evidence for this mechanism (see Table 4.3).

While uranium concentrations at the Lee wells are consistently below the limit of detection (0.010 mg/l), the Lee wells are completed in alluvium largely derived from non-ore bearing rock material. As ground water flows downvalley from the Lee well cluster, natural uranium concentrations are anticipated to increase gradually as ground water flows through a more uranium-enriched alluvium. Pre-mining uranium concentrations at the Sandoval Ranch are estimated to have been less than 0.030 mg/l, based on interpretation of gross alpha activity concentrations obtained from a 1975 sampling of an alluvial windmill at the ranch (U.S. EPA, 1975). Natural uranium concentrations may increase further downstream. U.S. EPA (1975) estimated that background concentrations may approach 0.1 mg/l within the Ambrosia Lake mining district.

8.1.4. Selenium

Under natural conditions selenium concentrations in alluvial ground water along the North Fork of the Puerco River are expected to be uniformily low, that is, less than 0.01 mg/l. Average concentrations in the two BLM wells are <0.005 and <0.007 mg/l. Further, analyses of unfiltered natural runoff indicates the virtual absence of selenium in sediments and natural waters in this drainage (see Table 4.3).

In contrast, along San Mateo Creek, natural selenium levels may be significantly elevated. Selenium is known to be locally enriched in soils and plants in the Poison Canyon area (Cannon, 1953; Rapaport, 1963). It is noteworthy that median total selenium concentrations in natural runoff are over six times greater in the Ambrosia Lake mining district than in the Church Rock mining district (see Table 4.3).

Selenium concentrations in the Lee wells are generally undetectable (<0.005 mg/l). A 1980 EID analysis of the downstream Sandoval Ranch windmill showed selenium concentrations of 0.018 mg/l (EID files). Although minewaters have been discharged to the San Mateo Creek above this well since 1976, the depth of the well (130 feet) moderates the impacts of the mine discharges and, as a worst case, the 1980 selenium concentration represents an upper limit estimate of the pre-mining concentration. Natural selenium concentrations in ground water may increase downstream from the Sandoval Ranch because of the probable contribution of selenium-enriched Poison Canyon sediments to the San Mateo Creek alluvium.

8.2 IDENTIFICATION OF IMPACTS ATTRIBUTABLE TO MINE DEWATERING EFFLUENTS

Due to the lack of pre-mining data, comprehensive descriptions of the impacts of mine dewatering can not be made for all locations. At many locations, however, minewater impacts can be indirectly estimated after joint consideration of several pieces of hydrogeochemical evidence. The principal indicators that suggest if ground water has been impacted at a given location include the following:

1. Molybdenum concentrations in alluvial ground water greater than 0.03 mg/l. Mine dewatering effluents are the principal sources of dissolved molybdenum in the Puerco River and San Mateo Creek channels. Runoff from uranium mine waste piles may contain detectable levels of dissolved molybdenum, but due to the infrequency of runoff events and dominantly sediment-bound nature of the waste pile contaminants, significant impacts to ground water, if any, should be restricted to the immediate vicinity of the waste pile. The presence of molybdenum in concentrations greater than 0.03 mg/l in alluvial wells along these channels is indicative of the presence of mine dewatering effluents. The absence of molybdenum in these wells, on the other hand, does not mean that minewater impacts are not evident because not all effluents contain elevated levels of molybdenum (see Table 7.3).

2. Uranium concentrations greater than 0.06 mg/l in alluvial ground water along the North Fork of the Puerco River, and greater than 0.03 mg/l upstream and 0.1 mg/l downstream of the confluence of San Mateo Creek with Arroyo del Puerto. The values constitute the estimated upper limit concentrations found in these ground waters under natural conditions.

3. Selenium concentrations greater than 0.01 mg/l along the North Fork of the Puerco River, and greater than 0.15 mg/l along the San Mateo Creek upstream of its confluence with Arroyo del Puerto. Natural selenium concentrations along these river reaches are expected to be relatively low. Natural conditions below the San Mateo Creek-Arroyo del Puerto confluence cannot be projected because of the uncertainty regarding the added influence of selenium-enriched Poison Canyon sediment on ground water quality.

4. Major changes in total dissolved solids concentrations and in general ground water chemistry composition within a distance less than 3 miles. Natural changes in TDS concentrations and in composition are expected to be gradual; rapid changes in both are indicative of minewater effects.

5. Significant decline in molybdenum, uranium, or selenium concentrations with increasing depth in the upper portion of an alluvial aquifer. Contaminants contributed to the aquifer through stream bottom recharge (as is the case with minewaters) are expected to be more concentrated in the upper portion of the aquifer than contaminants naturally occurring in the ground water.

8.3 CHANGES IN IONIC CHEMISTRY

Alluvial ground waters that are recharged primarily by dewatering effluents have been found to assume the ionic composition of the minewaters. Such water-quality changes are seen in areas of ground-water recharge along the Puerco River and San Mateo Creek. Pronounced changes in ionic composition of alluvial ground waters, for example, are seen at the Confluence test well cluster along the Puerco River. This well cluster is located about one mile below the confluence of Pipeline Arroyo, the channel receiving most of the Church Rock mine discharges, and the Puerco River. It is therefore immediately downgradient from the point where native ground waters are potentially affected by minewaters (see Figure 8.1).

Figure 8.5 shows that ground waters produced from wells CON-IL and CON-3 have ionic compositions similar to dewatering effluent and unlike natural waters, as represented by the BLM well cluster. Wells CON-IU and CON-2, on the other hand, produce waters more similar to natural waters. Ground water in well CON-3, which chemically most resembles the minewaters, also has a total dissolved solids concentration similar to minewaters (500 mg/l versus greater than 1000 mg/l at the BLM cluster). It is apparent that some water in the alluvial aquifer at that well cluster has been transformed from the strongly calcium-magnesium sulfate type to an intermediate type that tends toward sodium bicarbonate. Other test wells along the Puerco River that produce ground waters with ionic signatures similar to that for CON-3 are SPR-1, SPR-3U, GAL-1, GAL-2, and GAL-4. Because of the lack of pre-dewatering ground water quality data, it can not be definitely stated that all of these wells have been affected by the dewatering effluents.

The water quality of shallow ground waters in the San Mateo Creek-Arroyo del Puerto drainage has also been transformed by dewatering effluents. This change in major chemistry is most evident near the confluence of San Mateo Creek and Arroyo del Puerto (see Figure 8.2). One mile upstream along San Mateo Creek, alluvial ground waters at the Sandoval monitoring well cluster are of the sodium-sulfate-bicarbonate water chemistry type with a total dissolved solids concentration of about 650 mg/l (Figure 8.6). Although minewater from Ranchers Johnny M. Mine enters San Mateo Creek about 3 miles above the well cluster, no significant changes in ionic composition are evident in the test wells because of the close chemical similarity between minewaters and natural ground water at the site (see Sandoval Ranch windmill analysis, Figure 8.4).

In contrast, downstream from the confluence EID test wells on the San Mateo Creek produce alluvial ground water that bears a strong ionic resemblance to Ambrosia Lake minewaters. Figure 8.6 shows that ground waters at OTE-2, OTE-4, and RDY-1 now are all of the calcium-magnesium sulfate type, as are the minewaters introduced via Arroyo del Puerto. Corresponding to the shift in San Mateo Creek's alluvial ground water chemistry, total dissolved solids concentrations increased from about 650 mg/l at the Sandoval well cluster to over 2100 mg/l at the Otero well cluster, located three miles downstream.

8.4 TRACE ELEMENTS AND RADIONUCLIDES IN GROUND WATER

In addition to altering the dominant water chemistry and total dissolved solids concentrations of ground waters, infiltration of minewaters has elevated the concentrations of trace elements and gross radioactivity. Specifically, in test wells determined to have been affected by minewaters, the concentrations of uranium, molybdenum, selenium, and gross alpha particle activity are elevated above natural levels by 10 to 40 times. Evidence suggests that infiltration of mine effluents has caused similar responses elsewhere in the region beneath zones of significant stream bottom leakage

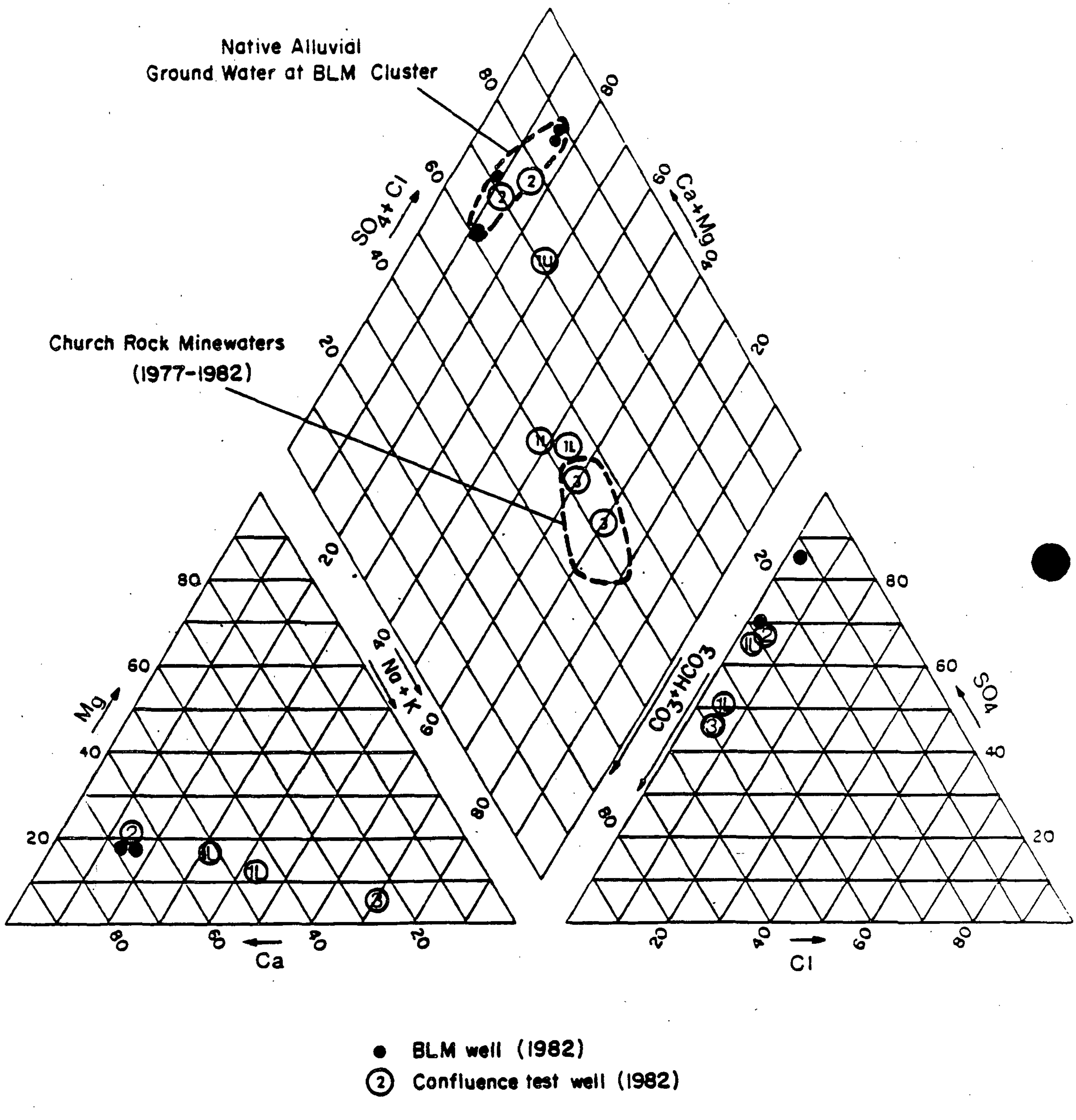


FIGURE 8.5 Ground water quality along the Puerco River near the BLM and Confluence well clusters.

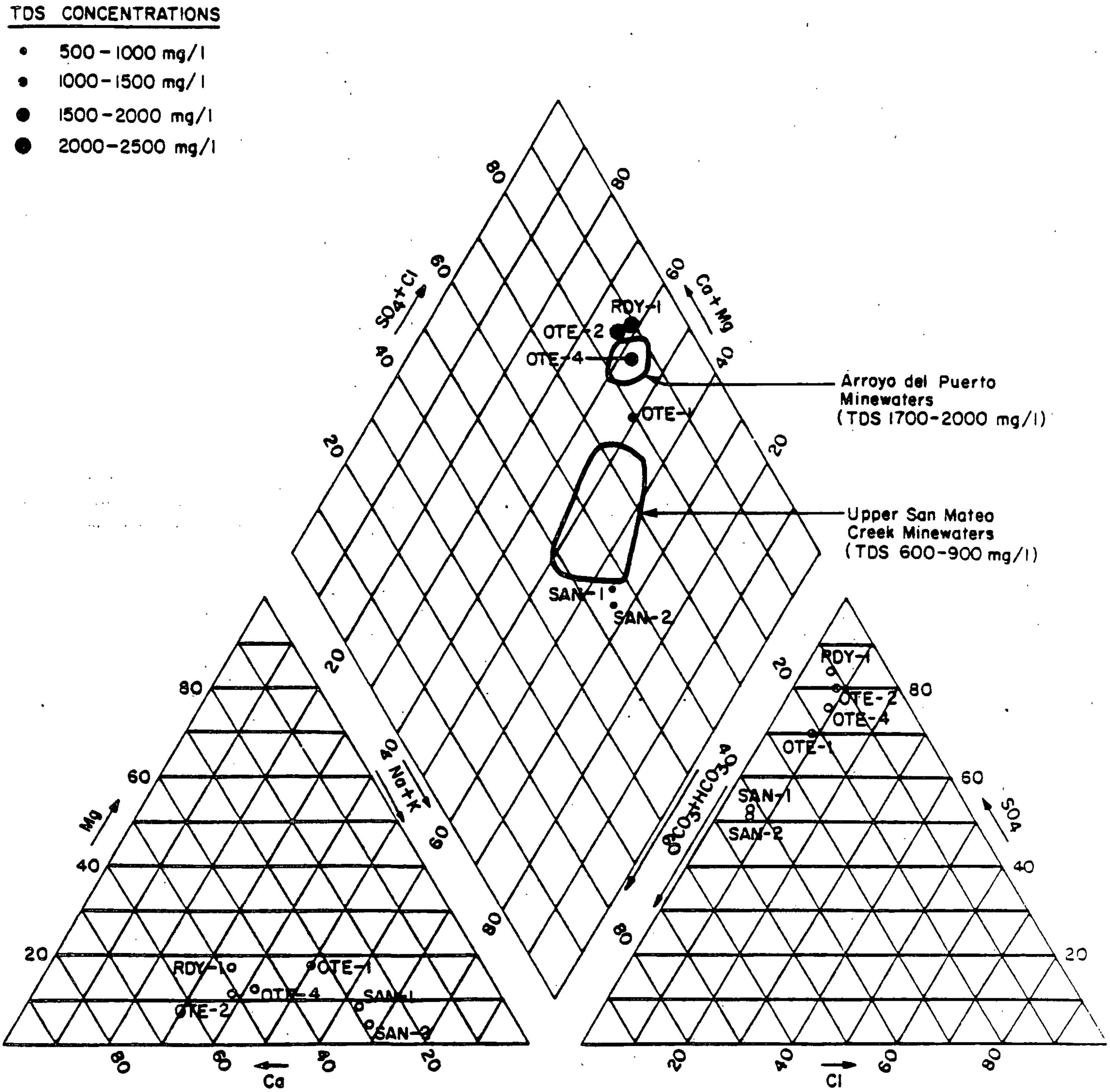


FIGURE 8.6 Ground water quality along San Mateo Creek

Degradation of ground water quality is most pronounced in the Ambrosia Lake mining district. This is to be expected for the following reasons: 1) approximately two-thirds of the historical minewater production from New Mexico uranium mining areas has been in this district (see Figure 6.1); 2) the quality of the discharged water overall is poorer than that in the Church Rock mining district (see Table 7.3); and 3) hydrogeologic conditions along Ambrosia Lake drainages result in relatively rapid infiltration of the wastewaters.

Table 8.1 shows mean contaminant concentrations detected in EID test wells along San Mateo Creek, the principal drainage of the Ambrosia Lake mining district. Uranium, molybdenum, and selenium concentrations at the Lee wells are below detectable levels of 0.005 to 0.01 mg/l. Uranium and molybdenum levels at the Sandoval well cluster are 10 to 20 times detectable limits due to infiltration of dewatering effluents. Other trace elements did not exhibit concentrations elevated above those found at the Lee wells.

Down valley below the confluence with the Arroyo del Puerto, uranium, molybdenum, and selenium concentrations are found to be approximately three times greater than at the Sandoval well cluster. Uranium and molybdenum concentrations in the Otero wells are as much 7 times greater than natural levels projected for this portion of the San Mateo Creek (see section 8.1) and therefore indicate that ground water at that location has been substantially degraded by minewaters. Moreover, both uranium and molybdenum significantly decline in concentration with increasing depth. (For example, molybdenum concentrations decline from 0.38 and 0.28 mg/l in the shallower wells OTE-1 and OTE-2 (54 and 57 feet total depth, respectively) to < 0.01 mg/l in well OTE-4, a deeper well (72 feet total depth) in the same cluster.) Selenium is elevated in all the Otero wells, but is known to be naturally enriched in the area and can not be exclusively attributed to mine dewatering effluents. Generally, the pattern of trace element concentrations in the Otero wells coincides with that of the Sandoval wells (uranium > molybdenum ≥ selenium).

As with uranium, gross alpha particle activity concentrations are also significantly elevated along the San Mateo Creek below the Lee wells. These concentrations almost exclusively reflect the alpha radiation of uranium. Gross beta particle activities along the San mateo Creek are found in concentrations as much as 100 times those detected at the Lee wells. It is unknown which radionuclide(s) contribute principally to the gross beta concentrations.

Radium-226 concentrations may also increase due to minewater impacts, but the increases can not be verified due to the lack of pre-mining data. Table 8.1 shows radium-226 concentrations of about 0.05 pCi/l for the Lee wells. All but one of the other test wells along San Mateo Creek produce water containing more than 0.10 pCi/l of radium-226, on the average. Student-t and Mann-Whitney statistical tests show that the mean values for radium-226 in all the minewater-affected wells are significantly greater (95% confidence) than levels at the Lee wells. Despite the suggestion that minewaters have elevated radium-226 levels in alluvial ground waters, this increase is small and of little practical significance. A measureable amount of radium-226 may reach ground water, but most of the dissolved radium-226 in surface waters (up to 4 pCi/l) clearly does not.

Due to lack of pre-mining data, definitive statements can not be made regarding the influence of mine dewatering effluents at the Roundy well location, the most downstream well on the San Mateo Creek drainage The average uranium concentration of 0.13 mg/l is slightly above the EPA-estimated maximum natural level of 0.1 mg/l. In contrast, however, molybdenum is below analytically detectable levels. Selenium levels are greatly elevated, but because ground water quality is potentially influenced by Poison Canyon, where sediments are enriched in selenium, these levels can not be exclusively attributed to minewaters.

TABLE 8.1. Mean Trace Element and Radionuclide Concentrations in Wells in the San Mateo Creek Drainage, 1977-1982. Number of samples for each well is shown in parentheses and standard deviations are specified for all means. Well locations are indicated on Figure 8.2.

	WELLS ABOVE URANIUM MINE DISCHARGES		WELLS BELOW URANIUM MINE DISCHARGES					
	LEE-1 (13)	LEE-2 (14)	SAN-1 (13)	SAN-2 (12)	OTE-1 (14)	OTE-2 (15)	OTE-4 (12)	RDY-1 (12)
				ug/l				
As	ND	6.8 ± 1.7	ND	ND	ND	6.8 ± 3.4	ND	5.9 ± 2.4
Ba	133 ± 38	113 ± 18	112 ± 28	108 ± 22	112 ± 33	132 ± 50	124 ± 40	139 ± 38
Cd	ND	ND	ND	ND	ND	ND	ND	ND
Pb	ND	ND	ND	ND	ND	ND	ND	ND
Mo	ND	9.6 ± 3.3	133 ± 60	131 ± 55	381 ± 115	257 ± 145	ND	ND
Se	ND	ND	18.5 ± 7.2	18.0 ± 7.7	80 ± 25	72 ± 25	102 ± 30	273 ± 128
U	ND	ND	222 ± 41	251 ± 79	754 ± 69	668 ± 144	166 ± 23	129 ± 11
V	ND	12 ± 2.7	ND	ND	ND	ND	ND	ND
Zn	ND	ND	ND	ND	ND	ND	ND	ND
				pCi/l				
Ra-226** (pCi/l)	0.05 ± .02	0.04 ± .02	0.15 ± .03	0.09 ± .03	0.11 ± .03	0.15 ± .06	0.13 ± .02	0.15 ± .03
gross alpha	4 ± 2	6.6 ± 1.05	184 ± 38	209 ± 69	496 ± 49	463 ± 49	123 ± 19	92 ± 13
gross beta	3 ± 2	4 ± 2	89 ± 37	96 ± 39	300 ± 93	291 ± 92	72 ± 33	63 ± 19

*ND = not analytically detected
**Radium-226 values reflect samples analyzed by the New Mexico Scientific Laboratory Division (SLD); for uniformity data by Eberline Instrument Corp. were not used in calculation of the mean

The UNC uranium mill tailings spill in July l979 greatly complicated the task of evaluating minewater impacts on alluvial ground waters in the Puerco River valley. The spill contained large concentrations of many radionuclides and trace elements, including the alpha emitters thorium-230 and uranium and the trace elements molybdenum, vanadium, and selenium. Thus, in all data collected since July l979 there are always two potential sources for contaminants: the spill and minewaters. There are some pre-spill data for the Gallup cluster, but no pre-spill data exist for the Entrada, Windmill, Springstead, or Confluence well clusters.

Despite this major obstacle, the sources of elevated uranium in Puerco River valley ground waters are indicated through the use of the same probability techniques used to estimate natural uranium levels. These analyses allow differentiation of ground waters influenced by the spill from those influenced by minewaters. Whereas those ground waters that are high in both uranium and sulfate have been affected by the UNC spill, which was enriched in sulfuric acid, those wells that produce high uranium, but low sulfate, have been affected by minewaters, but not the spill. Only these results of these analyses (Gallaher and Cary, 1986) related to wells affected by minewaters are summarized here.

Mine dewatering effluents have degraded Puerco River alluvium with trace elements and radionuclides, although not to the same degree as along San Mateo Creek. Results of the aforementioned probability analysis suggest that fewer than one-third (6 of 21) of the EID wells along the Puerco River have been significantly impacted by uranium industry activities (minewaters and spill waters). Relatively low infiltration rates along this reach of the river effectively moderate the impacts to the underlying ground water.

Two test wells, SPR-1 and CON-3, were found to contain elevated levels of uranium attributable principally to minewaters. Table 8.2 summarizes the trace element and radionuclide concentrations found in these two wells and in BLM wells representative of natural alluvial quality. The data indicate a pattern of minewater effects similar to that documented along San Mateo Creek. Uranium and gross alpha particle activity are clearly elevated above natural levels in the two downstream wells. Molybdenum also shows increases above background although for SPR-1 the increase is negligible as it is the detectable limit. A small increase in selenium concentrations is suggested in CON-3 samples.

While minewater impacts along a given river reach may be relatively limited, they may be more significant further downstream if stream bottom leakage rates increase because of changing hydrogeologic conditions. The resultant ground water quality impacts would be highly site specific, depending on many factors including the infiltration rate, quality of the minewaters, and natural quality of ground water.

In reviewing the data for trace elements and radionuclides, it is clear that dewatering effluents are having similar effects throughout the Grants Mineral Belt. Uranium and gross particle alpha activity concentrations are often elevated in alluvial ground waters downstream from minewater discharges. Molybdenum usually appears elevated although there are exceptions. Selenium also reaches shallow ground water from minewater sources. Selenium, however, can also be locally elevated under natural conditions in Ambrosia Lake. Unless confirmed by evidence of low pre-mining concentrations, the presence of elevated selenium is not alone sufficient to demonstrate contamination by mine dewatering effluents.

TABLE 8.2. Mean Trace Elements and Radionuclides Concentrations of Selected Wells in the Puerco River Valley. Number of samples per well is shown in parentheses.

CONSTITUENT (ug/1)	WELLS ABOVE URANIUM MINE DISCHARGES BLM 1U (2)	BLM-2 (2)	WELLS AFFECTED BY URANIUM MINE DISCHARGES SPR-1 (1)	CON-3 (2)
ug/l				
As	ND*	14	9	6
Ba	100	150	ND	180
Cd	ND	ND	ND	ND
Pb	ND	ND	ND	ND
Mo	ND	ND	10	170
Se	ND	7.5	5	11
U	14	48	145	433
V	ND	ND	ND	ND
Zn	ND	ND	ND	ND
pCi/1				
gross alpha	10±3	28±10	56±15	278±10
gross beta	2.6 ± 2.9	16±4	NA**	118±22
Ra-226	0.13±0.06	0.32±0.10	NA	0.37±0.12

*ND = Not analytically detected
**NA = Data not available; analysis not requested

8.5 GEOCHEMICAL ATTENUATION OF MINEWATER CONSTITUENTS

Ground water quality data collected from EID wells in the Grants Mineral Belt show uranium, radium-226, selenium, and molybdenum concentrations and gross alpha particle activity that are above natural levels, but not as high as in the discharged minewaters. For most of these contaminants, however, ground water concentrations are of the same order of magnitude as in the sources.

Mechanisms which may reduce the contaminant concentrations include dilution surface adsorption, cation exchange, precipitation, hydrodynamic dispersion, and molecular diffusion. Dispersion and dilution may eventually reduce contaminant concentrations, but these processes are slow and may take years or even decades to be effective. Dilution, adsorption, cation exchange and precipitation are more likely mechanisms.

Decreases of uranium, for example, from more than l.0 mg/l in minewaters to 0.5 mg/l in alluvial aquifers can probably be attributed to dilution by native ground waters. Uranium, molybdenum, and selenium all form anions in the geochemical environment of the Grants Mineral Belt and are therefore not greatly affected by some of the most effective attenuation processes, such as surface adsorption and cation exchange. These contaminants are therefore relatively mobile in both surface waters and shallow ground waters.

The tendency for uranium to precipitate from solution in Puerco River alluvium was analyzed using a computer program (WATEQFC) for calculating chemical equilibria of natural waters. Emphasis was placed on assessing the chemical stability of ground waters in EID wells most impacted by minewaters. Calculations were performed separately on natural uncontaminated ground water (BLM-1U) and on ground water dominated by mine dewatering effluents (CON-3). The predominant phase of uranium is calculated by the computer program WATEQFC to be di- oxide species. These complexes are subject to minimal adsorption because of their net negative charge and large molecular radii Tripathi, 1982; Langmuir, 1978) and are therefore very mobile in alkaline aqueous environments. Selected results of the geochemical modeling for the predominant uranium minerals are reported in Table 8.3.

The modeling output that all of the uranium species constituents are undersaturated with respect to their mineral phases by at least one hundred times. It can be inferred that uranium concentrations in the alluvial aquifer cannot be expected to decline solely as a result of long term equilibrium adjustment.

For dissolved radium-226, in contrast to uranium, the alkaline, oxidizing conditions found in the Grants Mineral Belt promote attenuation and discourage mobility. Because of its net positive charge, radium-226 is drawn to cation exchange sites on negatively charged clay minerals, organic matter, and metallic oxide coatings on the surfaces of alluvial materials. For surface and ground waters in the Grants Mineral Belt, only a small fraction of all radium-226 present remains in solution. Most radium-226 is probably immobilized in the stream channels sediments. Attenuation of radium-226 is so effective in Grants Mineral Belt alluvium that apparently minewaters increase the typical dissolved radium-226 concentrations normally carried by regional ground waters by only about 0.l pCi/l.

TABLE 8.3 Selected Mineral Saturation Indices for Uranium in Puerco River Alluvial Ground Water.

Well No.	Sample Date (M-D-Y)	Mineral or Precipitate Phase	Formula	Saturation Index
BLM-1U	01-19-82	Tyuyamunite	$Ca(UO_2)_2(V0_4)_2$	-4.9
CON-3	01-20-82	Tyuyamunite	$Ca(UO_2)_2(V0_4)_2$	-2.7
		Carnotite-A	$K2(UO_2)_2(VO_4)_2 \cdot 3H_20$	-3.3
		Carnotite-B	$K2(UO_2)_2(VO_4)_2 \cdot 3H_20$	-3.5
		Schoepite	$UO_2(OH)_2H_20$	-3.6
		Coffinite	$USi0_4$	-4.4
		Rutherfordine	$U0_2CO_3$	-4.4

Although data are lacking for other uranium-238 decay products, it seems unlikely that any of the major daughter products from uranium mining activities could significantly degrade ground-water quality within the alkaline pH ranges typical of the minewaters. Thorium-230, lead-2l0, and polonium-2l0 all form cations in solution and their attenuation is likely to be as effective as radium-226 attenuation. Overall, the threat to ground water is judged to be small.

IX. EVALUATION OF WATER QUALITY

Earlier chapters have provided an overview of both natural water quality in the Grants Mineral Belt and water quality impacted by uranium mining. In order to evaluate the significance of observed water quality, current and potential uses that are made of the water in this area need to be considered along with relevant aspects of surface and ground water hydrology and the physio-chemical fate of minewater constituents. Furthermore, because of the radioactivity associated with both natural and mining-impacted flows, the quality of these flows needs to be compared with established standards and criteria for public exposure.

All surface waters in the Grants Mineral Belt, whether natural or mining-impacted, are used by livestock for watering. Only artificially maintained perennial streams, however, are used for irrigation or have potential use for domestic water supply. All three uses are made of ground waters. The contaminant and radioactivity levels of surface and ground waters in the Grants Mineral Belth raises concerns about the suitability of natural and mining-impacted surface waters and mining-impacted ground waters for present and potential uses.

9.1 WATER USES

Comparison of water quality with criteria and standards provides a means of evaluating whether water quality in the Grants Mineral Belt is consistent with current use. Livestock watering is the major use of surface waters. Watering from effluent-dominated streams is commonplace. Livestock even use turbid flows that may include both natural runoff and runoff from mine tailings.

Irrigation of gardens is practiced along the Puerco River from the Highway 566 bridge to the City of Gallup. Hoses are used to draw water up from the incised stream to gardens.

Ground waters are used as domestic water supply sources. The authors know of no documented domestic use of surface waters in the Grants Mineral Belt. Nonetheless, the potential for effluent-dominated streams, as modified in chemical quality by physio-chemical processes, to affect the quality ground waters provides sufficient rationale to evaluate such streams as sources of domestic water supply. Moreover, municipalities have considered the possibility of using dewatering effluents to supplement existing water supply sources (Hiss, 1980).

Selected criteria and standards for livestock watering, irrigation, and domestic water supply are given in Table 9.1. The only comprehensive evaluation of water quality necessary to support livestock watering remains that done by the National Academy of Sciences-National Academy of Engineering (NAS/NAE, 1972) for the EPA. The NAS/NAE recommendations are in the form of water quality criteria, that is, concentrations which, if not exceeded, are expected to be suitable to support a specific water use. NAS/NAE (1972) also recommended water quality criteria to support irrigation use. As part of the Molybdenum Project, the relationship between molybdenum levels in irrigation waters and plants was investigated (Vleck and Lindsay, 1977). The New Mexico Ground Water Regulations include standards designed to protect ground water quality for agricultural use (NM WQCC, 1983). These standards are used in this report for comparison purposes only. The regulations should be consulted for information on the applicability of the standards.

TABLE 9.1. Selected Criteria and Standards for Livestock Watering, Irrigation, and Domestic Water Supply.

CONSTITUENT	WATER USE					
	Livestock Watering	Irrigation			Domestic Water Supply	
	NAS/NAE	NAS/NAE	Molybdenum Project	New Mexico Ground Water Regulations	New Mexico Water Supply Regulations	New Mexico Ground Water Regulations
	mg/l					
TDS	3,000			1,000		1,000
SO_4				600		600
As	0.2	0.10		0.1	0.05	0.1
Ba				1.0	1.	1.0
Cd	0.050	0.010		0.1	0.010	0.01
Pb	0.1	5.0		0.05	0.05	0.05
Mo			0.020	1.0		
Se	0.05	0.02		0.05	0.01	0.05
U-natural				5.0		5.0
V	0.1	0.10				
Zn	25	2.0		10.0	5.	10.0
	pCi/l					
Gross Alpha[a]	15				15	
Combined Ra-226 and Ra-228	5	5		30.0	5	30.0

SOURCES: NAS/NAE - NAS/NAE (1972)
Molybdenum Project - Vleck and Lindsay (1977)
New Mexico Water Supply [illegible]ions - NM EIB (1985)
New Mexico Ground Wate[illegible]gulations - NM WQCC (1983)

Two sources of comparison were used to evaluate the quality of water for domestic use. Standards in the New Mexico Water Supply Regulations (NM EIB, 1985) are applicable to water emanating from water supply systems, not to surface and ground waters and are used only for comparison purposes. Similarly, the standards in the New Mexico Ground Water Regulations (NM WQCC, 1983) are not applicable to effluent-dominated streams and are used only for comparison purposes. Both sets of regulations should be consulted for information on their applicability.

As both natural water quality and the quality of waters affected or produced by uranium mining contain radioactivity, standards and criteria in the New Mexico Radiation Protection Regulations (NM EID, 1980) are used as a basis of comparison. The Radiation Protection Regulations are not applicable to natural water quality or uranium mining and the standards and criteria are used only for purposes of comparison. The regulations should be consulted for information on applicability.

9.2 NATURAL SURFACE WATERS

Perennial streams in the Grants Mineral Belt are limited in number, extent, and flow. The other natural source of surface water is runoff associated with storms and snowmelt. Without mine dewatering, runoff would be the surface waters in the Arroyo del Puerto, San Mateo Creek below the community of San Mateo, and the Puerco River. Both natural perennial streams and natural runoff may be used by livestock for watering.

The quality of perennial streams, which normally carry little sediment, is consistent with the livestock watering use. Trace elements and radioactivity concentrations, however, raise concerns about the suitability of natural runoff for this use. Furthermore, levels of radioactivity in natural runoff are sometimes excessive in comparison to health criteria and standards.

9.2.1. Perennial Streams

Dissolved concentrations of trace elements and radionuclides are naturally low in perennial streams in the Grants Mineral Belt. Comparison of natural water quality with livestock watering criteria for six trace elements, gross alpha particle activity, and radium-226 indicates that natural concentrations are normally much less than the criteria (Table 9.2). Similarly, the livestock criteria of 3,000 mg/l total dissolved solids (NAS/NAE, 1972) is almost double the mean natural concentration of 1530 mg/l found in the Rio Moquino at the Jackpile Mine. The Rio Moquino has higher dissolved solids concentrations than the Rio Paguate or San Mateo Creek below San Mateo Reservoir.

9.2.2. Natural Runoff

Trace elements and radionuclides are found to have highly variable levels in natural runoff resulting from storms. These levels are statistically correlated with the amount of suspended sediment carried by the water. Despite the high amounts of sediment that are sometimes carried by natural runoff, livestock may still use these waters. Therefore, natural runoff quality was compared with livestock watering criteria for the same six trace elements used for the comparison with perennial stream quality, but with very different results.

TABLE 9.2. Comparison of Dissolved Concentrations of Trace Elements and Radioactivity in Perennial Natural Waters with Livestock Watering Criteria.

CONSTITUENT	MEDIAN CONCENTRATION	LIVESTOCK WATERING CRITERIA[a]
	mg/l	
As	<0.005	0.2
Cd	<0.001	0.050
Pb	<0.005	0.1
Se	<0.005	0.05
V	<0.010	0.1
Zn	<0.050	25
	pCi/l	
Gross alpha	2	15
Ra-226	0.1	5[b]

[a] The criteria are from NAS/NAE (1972).

[b] The criterion applies to combined radium-226 and radium-228.

Measured total concentrations of trace elements and radioactivity indicate that natural runoff quality may not be consistent with its use for livestock watering (Table 9.3). Lead, vanadium, gross alpha particle activity, and radium-226 are the primary constituents affecting the suitability of natural runoff for livestock watering as median concentrations of all four constituents exceed criteria in both the Ambrosia Lake and the Church Rock mining districts. Even though the gross alpha particle activity criterion excludes alpha activity due to natural uranium, the median gross alpha activities of 1200 and 720 pCi/l in the Ambrosia Lake and the Church Rock mining districts, respectively, far exceed corresponding natural uranium medians of 68 and 20 pCi/l (at equilibrium, 1 mg/l of natural uranium is equivalent to 677 pCi/l).

Of lesser concern are arsenic and selenium in the Ambrosia Lake district and arsenic and cadmium in the Church Rock district because of exceedances of livestock watering criteria by maximum concentrations. The maximum concentration of cadmium measured in the Ambrosia Lake district is at the criterion level.

State limits on allowable concentrations of radionuclides that maybe discharged to unrestricted areas (that is, areas not controlled for the purposes of protecting an individual from exposure to radiation or radioactive materials) provide another means of evaluating the relative importance of radionuclides concentrations. These maximum permissible concentrations (MPCs), however, apply only to state-licensed facilities, not to natural runoff (see NMEID, 1980). Comparison of natural runoff quality with MPCs indicates that radium-226 is of concern in areas unaffected by the uranium industry in the Church Rock mining district and both radium-226 and lead-210 are of concern in similar areas in the Ambrosia Lake district (Table 9.4). Polonium-210 exceeds half its MPC in the Church Rock district; all other radionuclides are present in small amounts compared to MPCs. While these data are limited, it does appear that the radiological quality of natural runoff may be worse in the Ambrosia Lake district than in the Church Rock district.

While radium-226 and lead-210 sometimes exceed MPCs in uncontaminated, natural runoff, natural radiation levels may be a cause for concern even when these radionuclides simply approach MPCs. A sample from the South Fork of the Puerco River on September 21, 1982, provides a typical example (Table 9.5). Both radium-226 and lead-210 occurred at about 75 percent of their respective MPCs in this sample. Even though no radionuclide in the sample exceeded its MPC, the sum of the ratio of each radionuclide concentration to its MPC exceeds 1.00 (actual value, 1.66) and thus is in excess of specifications set forth in Part 4, Appendix A, Note 1 of the New Mexico Radiation Protection Regulations (NM EID, 1980). Uranium industry facilities licensed under these regulations are not permitted to release water of this quality to unrestricted areas. Yet, watercourses in the Grants Mineral Belt may receive water of this quality simply as a result of natural circumstances.

TABLE 9.3. Comparison of Total Concentrations of Trace Elements and Radioactivity in Natural Runoff with Livestock Watering Criteria.

CONSTITUENT	AMBROSIA LAKE MINING DISTRICT Median	AMBROSIA LAKE MINING DISTRICT Maximum	CHURCH ROCK MINING DISTRICT Median	CHURCH ROCK MINING DISTRICT Maximum	LIVESTOCK WATERING CRITERIA[a]
			mg/l		
As	0.13	0.26	0.08	0.30	0.2
Cd	0.006	0.05	0.003	0.06	0.050
Pb	0.52	2.0	0.17	2.0	0.1
Se	0.03	0.15	<0.005	0.03	0.05
V	0.61	3.2	0.40	0.92	0.1
Zn	1.5	1.7	0.38	8.5	25
			pCi/l		
Gross alpha	1,200	2,100	720	1,600	15
Ra-226	15	321	19	47	5[b]

[a] The criteria are from NAS/NAE (1972).

[b] The criterion applies to combined radium-226 and radium-228.

TABLE 9.4. Comparison of Total Radioactivity in Natural Runoff with Maximum Permissible Concentrations for Releases to Unrestricted Areas. All concentrations are in picocuries per liter (pCi/l).

RADIONUCLIDES	AMBROSIA LAKE MINING DISTRICT		CHURCH ROCK MINING DISTRICT		MAXIMUM PERMISSIBLE Concentration[a]
	Median	Maximum	Median	Maximum	
Pb-210	88	720	53	74	100
Po-210		43[b]	80	450	700
Ra-226	15	321	19	47	30
Th-228			22	43	7,000
Th-230			24	42	2,000
Th-232			24	43	2,000
U-natural	68	379	149	203	30,000

[a] The maximum permissible concentrations are from Table II of Appendix A to Part 4 of the New Mexico Radiation Protection Regulations (NM EID, 1980). The concentrations are not applicable to natural runoff and are used only for comparison purposes.

[b] Only a single measurement is available.

TABLE 9.5. Total Radionuclide Concentration/Maximum Permissible Concentration Ratios for the South Fork of the Puerco River on September 21, 1982.

RADIONUCLIDE	CONCENTRATION (pCi/l)	MPC[a] (pCi/l)	CONCENTRATION/MPC RATIO
Pb-210	74 ± 12	100	0.74
Po-210	90 ± 3	700	0.13
Ra-226	23 ± 6	30	0.77
Th-230	42 ± 4	2,000	0.02
U-natural	14	30,000	0.0005
		TOTAL	1.66

[a]The maximum permissible concentrations are from Table 11 of Appendix A to Part 4 of the New Mexico Radiation Protection Regulations (NM EID, 1980). The concentrations are not applicable to natural surface waters and are used only for comparison purposes.

9.3 URANIUM MINE WASTE PILES AND OPEN PITS

A potential concern about degradation of surface water quality from uranium mining is runoff from uranium mining operations - specifically, from mine waste piles and open pit operations. Both surface and underground mining produce waste piles. While the waste piles vary considerably in respect to ore content, the existence of the piles creates the potential for trace elements and radioactivity to be carried by runoff into surface water courses. Similarly, open pit mining exposes the ore body and creates the potential for contamination of surface waters through runoff. Furthermore, open pit mines have large waste piles nearby which may be subject to erosion.

Investigation of the largest open pit mine in the Grants Mineral Belt, the Jackpile-Paguate mine, indicates that while certain radioactive parameters are significantly elevated downstream from the mine, water quality both upstream and downstream is consistent with the livestock watering use. Investigation of mine waste piles in the Ambrosia Lake mining district, however, indicates that runoff from the piles is of a considerably lesser quality than natural runoff. Thus, such runoff is definitely not suitable for livestock watering and raises concerns about its levels of radioactivity. Similar results are expected to be found in the Church Rock district.

9.3.1. Runoff From Mine Waste Piles

Runoff from uranium mine waste piles exerts a potentially significant impact on surface water quality in the Grants Mineral Belt because of the trace elements and radioactivity associated with sediment carried by this runoff. Similar to the situation with natural runoff, livestock may ingest such turbid waters.

Total concentrations of arsenic, cadmium, lead, selenium, vanadium, gross alpha particle activity, and radium-226 found in mine waste pile runoff in the Ambrosia Lake District are not consistent with ingestion of this water by livestock (Table 9.6). This conclusion remains true even after the gross alpha activity is corrected for the alpha activity due to natural uranium (1 mg/l is equivalent to 667 pCi/l), which is not included in the livestock watering criterion. The median and maximum uranium values of 389 and 41,800 pCi/l are far below the measured gross alpha activity levels. In fact, for all constituents except arsenic, maximum concentrations are one to four orders of magnitude above livestock watering criterion. Even for arsenic, the maximum concentration exceeds the livestock watering criterion by over seven times. The median concentration of arsenic, though, is at its criterion level and selenium levels normally do not exceed its criterion.

Even though maximum permissible concentrations (MPCs) for release of radionuclides to unrestricted areas do not apply to runoff from mine waste piles, comparison with MPCs provides a means of evaluating the relative importance of radionuclides concentrations. Even median concentrations of lead-210 and radium-226 exceed MPCs by an order magnitude and maximum concentrations exceed MPCs two and three orders of magnitude, respectively (Table 9.7). While natural uranium concentrations are normally below its MPC, this level was exceeded by the maximum measured concentration.

TABLE 9.6. Comparison of Total Concentrations of Trace Elements and Radioactivity in Mine Waste Pile Runoff in the Ambrosia Lake Mining District with Livestock Watering Criteria.

CONSTITUENT	MEDIAN	MAXIMUM	LIVESTOCK WATERING CRITERIA[a]
	mg/l		
As	0.21	1.5	0.2
Pb	0.56	2.5	0.1
Se	0.03	0.85	0.05
V	1.1	24.8	0.1
	pCi/l		
Gross alpha	10,800	420,000	15
Ra-226	650	34,900	5[b]

[a] The criteria are from NAS/NAE (1972).

[b] The criterion applies to combined radium-226 and radium-228.

TABLE 9.7. Comparison of Total Radioactivity in Mine Waste Piles in the Ambrosia Lake Mining District with Maximum Permissible Concentrations for Releases to Unrestricted Areas. All concentrations are in mg/l.

RADIONUCLIDE	MEDIAN	MAXIMUM	MAXIMUM PERMISSIBLE CONCENTRATIONS[a]
Pb-210	1,000	30,050	100
Ra-226	650	34,900	30
U-natural	389	41,800	30,000

[a] The maximum permissible concentrations are from Table II.of Appendix A to Part 4 of the New Mexico Radiation Protection Regulations (NM EID, 1980). The concentrations are not applicable to natural runoff and are used only for comparison purposes.

When the results of comparison with livestock watering criteria and MPCs are considered together, the obvious conclusion is that while the quality of natural runoff in the Ambrosia Lake mining district is poor, mine waste pile runoff is worse. While information on the quality of mine waste pile runoff in the Church Rock district was not collected, this same conclusion is expected to hold in that district also.

9.3.2. Effect of an Open-Pit Mine on Surface Water Quality

Streams above and below the Jackpile-Paguate open-pit mine are likely to be used for livestock watering. In comparison to water quality in the Rio Paguate and the Rio Moquino above the mine, total dissolved solids and dissolved levels of gross alpha particle activity and radium-226 are significantly elevated in the Rio Paguate below the mine. In addition, dissolved concentrations of some trace elements are slightly elevated.

Comparison of livestock watering criteria with dissolved concentrations below the mine indicates that all constituents except for gross alpha and radium-226 are much less than recommended criteria (Table 9.8). Only the recommended criterion for gross alpha activity is apparently exceeded. The criterion, however, based on the criterion for domestic water supply (NAS/NAE, 1972), excludes uranium and the mean natural uranium concentration of 0.12 mg/l below mine accounts for 81 pCi/l of alpha activity. Therefore, the gross alpha activity is within the standard and the streams both above and below the Jackpile-Paguate mine are suitable for livestock use.

9.4. RELATIONSHIP OF RUNOFF QUALITY TO STREAM QUALITY

Under natural conditions (i.e., without mine dewatering), flow in San Mateo Creek below the community of San Mateo and the Puerco River consists of waters derived from runoff. Comparison of natural runoff from storms with livestock watering criteria indicates that such waters are not suitable for livestock watering primarily because of excessive concentrations of lead, vanadium, gross alpha particle activity, and radium-226. Data, while restricted to the Ambrosia Lake mining district, indicates that runoff from uranium mine waste piles is even less suited for livestock watering because of even higher concentrations of the same constituents.

Nonetheless, there are two lines of evidence that, when considered together, suggest that the direct effects of runoff, natural or uranium mine waste pile, on water quality are primarily local in extent. First, trace elements and radionuclides in runoff are bound up with sediment. Both trace element and radionulcide concentrations in runoff have been found to have linear, first-order statistical correlations with sediment concentrations. Further, leach tests did not produce significant leaching of trace elements from mine wastes. In addition, investigations of the partitioning of lead-210 and radium-226 between suspended and dissolved phases of runoff indicate that almost all of the radioactivity is associated with the suspended phase.

Secondly, sediments from an area become mixed with other sediments carried by the watercourse and thus diluted and then deposited along the stream bottom. The investigations of sediment deposition downstream from the San Mateo mine waste pile serve as a case example. Sediments originally identifiable as having the waste pile as their source on the basis of trace element and radionuclide concentrations,

TABLE 9.8 Comparison of Dissolved Concentrations of Total Dissolved Solids, Trace Elements, and Radioactivity in the Rio Paguate below the Jackpile-Paguate Mine with Livestock Watering Criteria.

CONSTITUENT	MEDIAN CONCENTRATION	LIVESTOCK WATERING CRITERIA[a]
	mg/l	
TDS	1,705	3,000
As	0.006	0.2
Cd	0.002	0.050
Pb	<0.005	0.1
Se	0.006	0.05
V	0.010	0.1
Zn	<0.25	25
	pCi/l	
Gross alpha	79 ± 18[b]	15
Ra-226	3.7 ± 0.14	5[c]

[a] The criteria are from NAS/NAE (1972).

[b] The gross alpha particle criterion excludes alpha activity due to natural uranium. Therefore, while the mean apparently exceeds the criterion, actually the gross alpha is accounted for by the mean natural uranium concentration of 0.12 mg/l, which is equivalent to 81 pCi/l.

[c] The radium criterion applies to combined radium-226 and radium-228.

eventually become so mixed with other sediments as to no longer be chemically distinguishable. This phenomon has been noted by Popp and others (1983).

Watercourses of the Grants Mineral Belt, nonetheless, are dynamic systems. While dilution and deposition of sediments serve as natural mechanisms that limit adverse water quality impacts of runoff, such sediments do not necessarily remain deposited on channel bottoms. Instead, storm runoff or flow resulting from mine dewatering may entrain sediment and thus result in resuspension, further mixture, and later redeposition downstream. Thus, re-entrainments and later redeposition serves as a process for carrying trace elements and radioactivity downstream in Grants Mineral Belt watercourses.

9.~~6~~5 IMPACT OF MINEWATER DISCHARGES ON SURFACE WATER QUALITY

In terms of both quantity and quality, discharged minewaters are the dominant type of surface waters in the Grants Mineral Belt. Treated minewaters are used directly for livestock watering and irrigation and thus should be evaluated for suitability for these uses. Further, they infiltrate to shallow alluvial aquifers and may thus secondarily be used as a source of domestic water supply. Therefore, direct comparison of treated minewater quality with domestic water supply standards indicate the changes in chemical quality, whether by natural means or treatment, that treated minewaters must undergo to be suitable as domestic water sources.

In the Ambrosia Lake mining district, the treated minewater constituents of greatest concern in relation to water uses are selenium, radium-226, and secondarily molybdenum (Table 9.9). Selenium normally exceeds standards and criteria established for livestock watering, irrigation, and domestic water supply. Selenium is of special concern as it remains soluble as minewaters flow downstream. Median radium-226 concentrations slightly exceed both the livestock watering and irrigation criteria and the New Mexico Water Supply Regulations standard for domestic water supply. The maximum radium-226 concentration also exceeds the New Mexico Ground Water Regulations standard for protection of ground waters for domestic water supply use. While radium-226 readily becomes adsorbed onto sediment or is co-precipitated and thus through these mechanisms tends to become deposited on stream bottoms, the radium-226 associated with sediments may also be later entrained and transported downstream by runoff or dewatering effluents.

While minewaters are not known to be used for irrigation in the Ambrosia Lake mining district, the use of minewaters for irrigation in the Church Rock district indicates that potential for such use exists. Molybdenum levels are normally more than a magnitude higher than the criterion recommended by Vleck and Lindsay (1977) to prevent excessive plant uptake of molybdenum. Further, while molybdenum levels normally meet the considerably higher New Mexico Ground Water Regulations standard for protection of ground water for irrigation use, the maximum measured molybdenum level even exceeds that less restrictive standard by a factor of three. Molybdenum like selenium remains in solution.

Concentrations of other constituents shown on the table raise further concerns about the use of treated minewaters in the Ambrosia Lake mining district. Total dissolved solids and sulfate concentrations normally exceed the New Mexico Ground Water Regulations standard for protection of ground waters for irrigation and domestic water supply use. Arsenic meets the livestock watering criterion, but the

TABLE 9.9 Comparison of Total Concentrations in Minewater Discharges in the Ambrosia Lake Mining District with Water Use Criteria and Standards.

CONSTITUENT	MINEWATER CONCENTRATIONS: Median	MINEWATER CONCENTRATIONS: Maximum	USE CRITERIA AND STANDARDS: Livestock Watering (NAS/NAE)	Irrigation (NAS/NAE)	Irrigation (The Molybdenum Project)	Irrigation (NM Ground Water Regulations)	Domestic Water Supply (NM Water Supply Regulations)	Domestic Water Supply (NM Ground Water Regulations)
mg/l								
TDS	1,610	2,615	3,000			1,000		1,000
SO_4	755	1,370				600		600
As	0.011	0.20	0.2	0.10		0.1	0.05	0.1
Ba	0.21	1.7				1.0	1.	1.0
Mo	0.80	3.2			0.020	1.0		
Se	0.09	1.0	0.05	0.02		0.05	0.01	0.05
U natural	1.56	3.0				5.0		5.0
V	0.029	0.29	0.1	0.10				
pCi/l								
Gross Alpha[a]	635	1,760	15				15	
Ra-226[b]	6.4	200	5	5			5	30

NOTE: Information on the sources of the use criteria and standards is found in Table 9.1.

[a]The gross alpha particle activity criteria exclude alpha activity due to natural uranium. Therefore, while the measured concentrations apparently are exceedances, the median and maximum natural uranium concentrations account for 1,060 and 2,030 pCi/l, respectively.

[b][illegible]

maximum arsenic level exceeds its irrigation criterion and standard and its domestic water supply standards. While barium levels normally meet the New Mexico Water Supply Regulations standard for domestic water supply and the New Mexico Ground Water Regulations standard for protection of ground waters for irrigation and domestic water supply use, the maximum barium level exceeds these standards. In a similar manner, vanadium levels normally meet and the maximum level exceeds livestock watering and irrigation criteria.

Gross alpha particle activity levels, which exceed the numeric levels of both the livestock watering criterion and the New Mexico Water Supply Regulations standard for domestic water supply, are accounted for by the alpha activity of natural uranium and thus are not exceedances as the criterion and the standard do not include alpha activity due to natural uranium. There is actually a large disparity between the calculated natural uranium alpha activity and the lower measured gross alpha activity levels as the median and maximum alpha activity levels for uranium are 1,060 and 2,030 pCi/l, respectively. Such differences, though, are common as a result of the difficulties of measuring gross alpha activity.

In the Church Rock mining district, the treated minewater constituents of greatest concern in relation to water uses are selenium and radium-226 (Table 9.10). Selenium normally exceeds criteria and standards established for livestock watering, irrigation, and domestic water supply. Maximum radium-226 concentrations exceed livestock watering and irrigation criteria and domestic water supply standards.

Of lesser concern in the Church Rock district are barium and molybdenum. Barium is normally below its New Mexico Ground Water Regulations standard for protection of ground waters irrigation and domestic water supply, but the maximum observed concentration was slightly higher than twice the standard of 1.0 mg/l. Molybdenum levels are normally less than the irrigation criterion recommended by Vleck and Lindsay (1977) and even the maximum level is only about one-half the New Mexico Ground Water Regulations standard for protection of ground waters for irrigation use. The irrigation criterion, however, is exceeded by the maximum observed level. While the maximum measured total dissolved solids concentration of 1,190 mg/l exceeds the New Mexico Ground Water Regulations standard for protection of ground waters for irrigation and domestic water supply use, concentrations are normally less than half the standard.

Gross alpha particle activity exceeds the numeric level of both the livestock watering criterion and the New Mexico Water Supply Regulations standard for domestic use since the criterion and the standard do not include alpha activity due to natural uranium, these levels are not exceedances. The median and maximum natural uranium concentrations are equivalent to 724 and 1,220 pCi/l of alpha activity, respectively. The differences between gross alpha activity and the calculated alpha activity due to natural uranium are attributable to the difficulties of measuring accurate gross alpha activity levels accurately.

In summary, comparisons of treated minewater quality with criteria and standards raises concern about the suitability of these waters for livestock watering, irrigation, and domestic water supply uses. Treated minewaters in the Ambrosia Lake district are poorer in quality and less suitable for these uses than those in the Church Rock district (Table 9.11). Overall, the major constituents affecting the suitability of treated minewaters are selenium, molybdenum, radium-226, total dissolved solids, and sulfate. Of these five, total dissolved solids and sulfate are the least important, as these waters are not known to be used as domestic water

TABLE 9.1[illegible] Comparison of Total Concentations of Minewater Discharges in the Church Rock Mining District with Water Use Criteria and Standards.

CONSTITUENT	MINEWATER CONCENTRATION		USE CRITERIA AND STANDARDS					
	Median	Maximum	Livestock Watering (NAS/NAE)	Irrigation (NAS/NAE)	Irrigation (The Molybdenum Project)	Irrigation (NM Ground Water Regulations)	Domestic Water Supply (NM Water Supply Regulations)	Domestic Water Supply (NM Ground Water Regulations)
	mg/l							
TDS	452	1,190	3,000			1,000		1,000
SO_4	136	600				600		600
As	<0.005	0.02	0.2			0.1	0.05	0.1
Ba	0.413	2.1				1.0	1.	1.0
Mo	0.01	0.6			0.020	1.0		
Se	0.042	0.3	0.05	0.02		0.05	0.01	0.05
U-natural	1.07	1.8				5.0		5.0
V	0.012	0.07	0.1	0.10				
	pCi/l							
Gross Alpha[a]	440	1,200	15				15	
Ra-226[b]	2.0	89	5	5			5	30

NOTE: Information on the sources of the use criteria and standards is found in Table 9.1.

[a]The gross alpha particle activity criteria exclude alpha activity due to natural uranium. Therefore, while the measured concentrations apparently are exceedance, the median and maximum natural uranium concentrations account for 724 and 1,220 pCi/l, respectively.

[illegible]

TABLE 9.11. Constitutents of Treated Minewaters and Affected Water Uses. Major constituents affecting water uses are indicated by M; secondary constituents by S.

Constituent	AMBROSIA LAKE MINING DISTRICT			CHURCH ROCK MINING DISTRICT		
	Livestock Watering	Irrigation	Domestic Water Supply	Livestock Watering	Irrigation	Domestic Water Supply
TDS		M	M		S	S
SO_4		M	M			
As		S	S			
Ba		S	S		S	S
Mo		M			S	S
Se	M	M	M	M	M	M
V	S	S				
Ra-226	M	M	M	S	S	S

NOTE: A constituent affecting a water use is considered major if the median concentration exceeds the most sensitive criterion or standard given in Table 9.1 for a specific use (i.e., measured levels normally exceed the criterion). A constituent is considered secondary if the median meets, but the maximum exceeds the most sensitive criterion or standard for a specific use (i.e., while measured levels normally meet the criterion, exceedances are found).

supplies or, in the Ambrosia Lake district where total dissolved solids concentrations are higher, for irrigation. Further, a compliance evaluation of total dissolved solids and sulfate in relation to irrigation use would need to consider individual ions, soils, crops, and acceptable yields. As mentioned earlier, radium-226 decreases as waters flow downstream from adsorption and co-precipitation and deposition, but may be resuspended. Selenium and molybdenum, however, remain soluble and thus continue to affect water use downstream as well as at the point of discharge.

Most radionuclides in treated minewaters are well below the maximum permissible concentrations (MPCs) for releases to unrestricted areas except for radium-226 (Table 9.12). While the MPCs apply only to state-licensed facilities and not to treated minewaters, here again MPCs serve as a useful basis for comparison. Radium-226 concentrations are normally below its MPC, but maximum levels exceed the MPC by almost three and seven times in the Church Rock and Ambrosia Lake mining districts, respectively. The maximum levels reflect poor operation of treatment systems. The only other radionuclide present in significant amounts in relation to its MPC is lead-210 in the Ambrosia Lake district. The median and maximum measured concentrations are 1/7 and 1/3 the MPC, respectively. Both radium-226 and lead-210 are usually lost from by becoming sediment-bound and deposited on stream bottoms, but may later be resuspended.

Animals exposed to Puerco River water tend to have higher concentrations of radionuclides in their tissues than control animals (Ruttenber and others, 1980). Evidence suggests that observed radionuclide concentrations have resulted from prolonged ingestion of contaminants predominantly derived from mine dewatering effluents and native soils. A separate EID study (Lapham and Millard, 1983) is intended to examine livestock throughout the Grants Mineral Belt and to quantify the risk to people who eat these animals.

While no current health standard for uranium was exceeded in treated minewaters, recent data suggest that chemical and radiological toxicities for uranium have been substantially underestimated. The New Mexico Ground Water Regulations standard of 5.0 mg/l was established for chemical toxicity, and the MPC for releases to unrestricted areas, equivalent to 44.3 mg/l, is based on radiotoxicity. In contrast, suggested maximum daily limits for potable water, developed from recent data by the U.S. Environmental Protection Agency (1983), are 0.21 mg/l and 0.015 mg/l based on chemical toxicity and radiotoxicity, respectively. If these more stringent limits are used for comparison, virtually none of the effluent affected waters would be considered suitable for potable water without further treatment.

9.6 IMPACT OF MINEWATER DISCHARGES ON GROUND WATER QUALITY

Dewatering effluents have infilterated shallow alluvial aquifers to such an extent that ground waters along San Mateo Creek downstream from the Ambrosia Lake mining district to the Otero well cluster and in localized areas along the Puerco River downstream from the Church Rock mining district now have a strong chemical resemblance to treated minewaters. Comparison of mean values for five wells along San Mateo Creek and two wells on the Puerco River determined to be affected by minewaters with use criteria and standards indicates that only molybdenum, selenium, and perhaps gross alpha are currently found in high enough concentrations to raise concerns about the suitability of shallow ground waters for livestock watering, irrigation, and domestic water supply uses (Table 9.13). Concentrations of other constituents are well below use criteria and standards.

TABLE 9.12. Comparison of Total Radioactivity in Minewater Discharges with Maximum Permissible Concentrations for Releases to Unrestricted Areas. All concentrations in pCi/l.

RADIONUCLIDES	AMBROSIA LAKE MINING DISTRICT		CHURCH ROCK MINING DISTRICT		MAXIMUM PERMISSIBLE CONCENTRATION[a]
	Median	Maximum	Median	Maximum	
Pb-210	14 ± 5	33 ± 6	---	10 ± 2[b]	100
Po-210	1.1 ± 0.4	14 ± 2	9.8 ± 7.4	15 ± 5	700
Ra-226	6.4 ± 1.2	200 ± 10	2.0 ± 0.2	89 ± 5	30
Ra-228	0 ± 2	0 ± 2	---	0 ± 2[b]	30
Th-228	<0.1	<0.3	---	<0.2[b]	7,000
Th-230	0.7 ± 0.2	4.0 ± 0.5	---	3.9 ± 0.5[b]	2,000
Th-232	<0.1	<0.1	---	<0.2[b]	2,000
U-natural[c]	1,060	2,030	724	1,220	30,000

[a] Maximum permissible concentrations are from Table II of Appendix A to Part 4 of the New Mexico Radiation Regulations (NM EID, 1980). The concentrations are not applicable to treated minewaters and are used only for comparison.

[b] Only two samples were analyzed for this radionuclide in the Church Rock mining district.

[c] Uranium radioactivity was calculated from total concentrations in mg/l by using the conversion facor, 1.0 mg/l equals 677 pCi/l.

TABLE 9.13. Mean Concentrations of Ground Water Constituents Exceeding Use Criteria and Standards.

WELL	MOLYBDENUM Mean Concentrations (mg/l)	MOLYBDENUM Affected Use	SELENIUM Mean Concentrations (mg/l)	SELENIUM Affected Use	GROSS ALPHA Mean Concentrations (pCi/l)	GROSS ALPHA Affected Use
San Mateo Creek						
SAN-1			0.018	DWS	184 ± 38	LW, DWS
SAN-2			0.018	DWS	209 ± 69	LW, DWS
OTE-1	0.381	IRR	0.080	LW, IRR, DWS		
OTE-2	0.261	IRR	0.072	LW, IRR, DWS		
OTE-4			0.102	LW, IRR, DWS		
Puerco River						
CON-3	0.170	IRR	0.011	DWS		

NOTE: The following use criteria and standards were used in preparing the table:

LW (livestock watering)

Se	0.05 mg/l	NAS/NAE (1972)
Gross alpha	15 pCi/l	NAS/NAE (1972)

IRR (irrigation)

Mo	0.150 mg/l	The Molybdenum Project (Vleck and Lindsay, 1977)
Se	0.02 mg/l	NAS/NAE (1972)

DWS (domestic water supply)

Se	0.01 mg/l)	New Mexico Water Supply Regulations (NM EIB, 1977)
Gross alpha	15 pCi/l (except for uranium and radon)	New Mexico Water Supply Regulations (NM EIB, 1977)

Selenium is the major constituent affecting the suitability of ground water for present and future use. The most sensitive use is domestic water supply; the least sensitive, livestock watering. Selenium concentrations in all five wells along San Mateo Creek and in one of the two wells (CON-3) on the Puerco River exceed the standard for public water supplies in the New Mexico Water Supply Regulations. The mean for CON-3, though, is essentially at the level of the standard. In addition, the three wells located farthest downstream on the San Mateo have selenium concentrations well above use criteria and thus are not suitable for livestock watering and irrigation. The molybdenum criterion for irrigation is exceeded at two wells in the Otero cluster along San Mateo Creek and at CON-3 on the Puerco River.

Gross alpha particle activity is generally elevated in ground waters influenced by dewatering effluents, but this increase is usually the result of natural uranium and thus does not constitute an exceedance of the livestock watering criterion and public water supply standard of 15 pCi/l. Only SAN-1 and SAN-2 had excess gross alpha activities of 34 and 39 pCi/l, respectively, not accounted for by natural uranium levels. Because of the difficulties involved in measuring gross alpha particle activity accurately and resulting errors associated with such measurements, these excess levels may be artifacts.

Comparison of ground water quality with use criteria and standards raises definite concerns about shallow alluvial aquifers along San Mateo Creek. The suitability of these ground waters for future use has already been affected. Unfortunately, sufficient data are not available to examine trends and to make predictions on future water quality.

Conclusions on ground waters along the Rio Puerco are not so clear-cut. The alluvium along the Rio Puerco is less permeable than along San Mateo Creek with the results that affected areas are more localized. Further, effects of the UNC tailings spills in local areas on the shallow aquifer has obscured possible effects related to dewatering. The levels of selenium and molybdenum, however, in CON-3, while lower than levels in wells along San Mateo Creek, indicate that there is a potential for sufficient degradation of ground water along the Puerco River to affect future water uses.

No current health standard for uranium is exceeded in alluvial ground waters. If the more stringent suggested limits discussed in section 9.5 are used for comparison, however, virtually none of the minewater affected ground waters would be suitable for potable water without further treatment. Because elevated levels of uranium may persist in alluvial aquifers for a decades, this treatment would have to be sustained for long period of time.

040WM067170E

UMTRA-DOE/AL

wm-67
050516
.0000

not for public dist.
no PDR
(Hold) wm-67
91-0057

United States Department of Energy

Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico

Final

Volume I: Text; Appendices A, B, and C

Appendix B of the Cooperative Agreement No. DE-FC04-85AL19454

September 1990

PDR cy hold
Copy attached

Uranium Mill Tailings Remedial Action Project UMTRAP

OFFICIAL DOCKET COPY

OFFICIAL DOCKET COPY

~~9009280054~~ 847 pp.

90-0843

EXECUTIVE SUMMARY
REMEDIAL ACTION PLAN
AMBROSIA LAKE, NEW MEXICO, SITE

Background

The Ambrosia Lake inactive uranium mill site, also known as the former Phillips-United Nuclear site, is in McKinley County, New Mexico, approximately 25 road miles north of Grants, New Mexico (see Figure 3.1). The 195.6-acre designated site consists of the 111-acre tailings pile, the mill yard, and piles of demolition rubble awaiting burial. The site contains 2.659 million cubic yards of tailings including 277,000 cubic yards of contaminated material in the mill yard, ore storage area, and Ann Lee Mine area; 151,000 cubic yards in the protore storage and leach pad areas; and 664,000 cubic yards of windblown contaminated soil, including excess soil that would result from excavation.

Remedial action

The remedial action will start with the excavation of windblown contaminated material and placement around the west, south, and east sides of the pile to buttress the slopes for increased stability. Most of the demolition rubble will be placed in the southern part of the pile and be covered with tailings. The northern part of the tailings pile (one million cubic yards) will then be excavated and placed on the south part of the pile to reduce the size of the disposal cell footprint. Demolition rubble that meets guidelines for uncontaminated material will be disposed of in a separate pit adjacent to the disposal cell within the final repository area. The remainder of the windblown contaminated material will then be placed on top of the tailings pile. A radon/infiltration barrier composed of compacted weathered Mancos Shale will be placed on top of the windblown contaminated material to control the release of radon gas and to restrict infiltration. A sand filter layer will be placed on top of the radon/infiltration barrier and will be covered with rock riprap to protect the disposal cell from erosive forces. After completion of the remedial action, the U.S. Department of Energy (DOE) will be responsible for complying with the U.S. Nuclear Regulatory Commission general license and perform surveillance and maintenance at the final restricted site.

Pursuant to the requirements of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), the proposed remedial action plan (RAP) will satisfy the U.S. Environmental Protection Agency (EPA) standards (40 CFR 192) for cleanup, stabilization, and control of the residual radioactive materials (referred to as tailings or contaminated material) at the Ambrosia Lake site. The requirement for control of the tailings (Subpart A) will be satisfied by the construction of an engineered disposal cell. Compliance with the groundwater requirements of 40 CFR 192 Subpart A will be through meeting supplemental standards (see Appendix E, Groundwater Protection Strategy). The site is eligible for supplemental groundwater standards due to the presence of Class III or limited use groundwater in the uppermost aquifer (the alluvium/weathered Mancos Shale and Tres Hermanos-C Sandstone), because the uppermost aquifer is incapable of producing 150 gallons per day or more for a sustained period of time (see Section D.8.4 of Appendix D).

In addition to insufficient yield, the water contained in the alluvium/weathered Mancos Shale and Tres Hermanos-C Sandstone is of poor quality and cannot be used for drinking or other beneficial purposes. A potential point of exposure could be from consumption of water from the Westwater Canyon Member of the Morrison Formation. Contaminated groundwater may have migrated down mine shafts and vent shafts into the Westwater Canyon Member in the past and is expected to continue on a much smaller scale after the tailings are stabilized. However, past and present mixing of the contaminated groundwater with the Westwater Canyon Member groundwater has had negligible effect on water quality in the Westwater and, as a result, no additional risk to humans or the environment is expected in the future. The Westwater Canyon Member is a source of drinking water in the area, but due to mining in the region, water quality has already deteriorated to the extent that there is some risk to humans or animals who consume it. Water in the Westwater Canyon Member exceeds the EPA maximum concentration limits for cadmium, chromium, lead, molybdenum, selenium, silver, uranium and activities of radium 226, radium 228 and gross alpha.

A supplemental standards discussion was prepared (see Addendum A to Appendix E) and includes a risk assessment to evaluate the existing water quality and to substantiate that the proposed supplemental standards are protective of human health and the environment. The site design will perform as close to meeting the otherwise applicable standards as is reasonably achievable. Infiltration through the disposal cell will be minimized by creating compaction and moisture conditions in the radon/infiltration barrier that will ensure the radon/infiltration barrier remains unsaturated. However, to be conservative, the radon/infiltration barrier was assumed to be saturated, which would result in an infiltration rate that is higher by approximately one order of magnitude. The 3.5-foot-thick barrier also will reduce radon release to below the EPA standard of 20 picocuries per square meter per second. A coarse-grained, six-inch-thick filter layer will be placed on top of the radon/infiltration barrier at a slope of four percent on the top and 20 percent on the sides to encourage runoff of precipitation. The combination of design features will enable the cell to comply with the EPA standards.

With the exception of the relic groundwater plume, the standards for the cleanup of the site under Subpart B of 40 CFR 192 will be satisfied with the proposed remedial action. Cleanup of the mill yard, windblown contaminated areas, and demolition rubble will be accomplished by consolidating the contaminated materials into the disposal cell. The DOE will verify that cleanup to standards has been accomplished. Cleanup of the relic groundwater plume will be addressed in another DOE program in a separate National Environmental Policy Act process at a later time. The supplemental standards application in Addendum A to Appendix E concluded that significant health risk is not present and is not expected due to contaminated groundwater.

<u>Groundwater monitoring</u>

Groundwater quality will be monitored in wells during the construction period. However, post-closure groundwater quality monitoring is not proposed at Ambrosia Lake and is not needed because water in the uppermost aquifer, the alluvium/ weathered Mancos Shale and Tres Hermanos-C sandstone, has a very

UMTRA-DOE/AL-050516.0000
July 1989

URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT OFFICE

ALBUQUERQUE OPERATIONS OFFICE

DEPARTMENT OF ENERGY

ALBUQUERQUE, NEW MEXICO 87108

REMEDIAL ACTION PLAN

AND

SITE DESIGN FOR STABILIZATION

OF THE

INACTIVE URANIUM MILL TAILINGS SITE

AT

AMBROSIA LAKE, NEW MEXICO

PRELIMINARY FINAL

APPENDIX B

OF THE

COOPERATIVE AGREEMENT NO. DE-FC04-85AL20533 limited areal extent and the quality is so poor that no future use is expected. Furthermore, no additional degradation of groundwater quality can occur because existing levels of saturation in the alluvium weathered Mancos Shale and Tres Hermanos-C sandstone are derived from uranium processing activities at the site. Monitoring in the deeper Westwater Canyon Member (which is hydraulically connected to the uppermost aquifer) is also not proposed because it is not possible to distinguish water quality changes in the Westwater Canyon Member that would be attributable to the seepage from the Ambrosia Lake disposal cell. Even though post-closure groundwater quality monitoring is not proposed, the public is still protected as described in Addendum A of Appendix E.

RAP changes

The major changes to the Ambrosia Lake RAP that have been made since the preliminary final RAP was issued in May 1987 are to demonstrate compliance with the EPA groundwater protection standards.

Specific changes to the RAP are as follows.

- o Inclusion of this executive summary.
- o Section D.8, Groundwater Hydrology in Appendix D, has been rewritten to describe the results of sampling from monitor wells installed in 1989 and to report results of monitor well falling head slug withdrawal and pumping tests.
- o Appendix E in the current RAP is now a discussion of the water resources protection strategy including Addendum A that consists of a supplemental groundwater standards discussion and related risk assessment. A summary of the strategy is also contained in Section 5.0 of the main RAP text.
- o Appendix F now contains the updated site design, specifications, and drawings that formerly were presented in Appendix E of the May 1987 preliminary final RAP. Revision of the site design, Appendix F, to (1) delete work that has been performed in one of the other Ambrosia Lake subcontract packages, and (2) incorporate changes recognized in responses to comments. Two minor cover enhancements will be issued in the near future to change the radon/infiltration barrier compaction to 100 percent of standard Proctor density and to require a coarser filter layer.
- o Clarification of mineral extraction activity in Section 3.5.6, Mineral Resources.
- o Revision of demolition rubble disposition in Section 4.2, Design Summary; Section 4.3.4, Demolition; and Section 4.4.3, Demolition.
- o Clarification of health and safety issues in Section 6, Environmental Health and Safety.

- o Update of radiological survey and verification procedures in Appendix C.

- *o Revision of Appendix A describing hazardous waste management.*

- o Three addenda were included with the preliminary final RAP (May 1987) that have not been reproduced in the current version of the RAP: Addendum D1 - Summary Radiological Data; Addendum D2 - Seismic Event Catalogs; and Addendum D3 - Geotechnical Logs. Please refer to the May 1987 RAP for this information.

<u>Design options considered but not incorporated</u>

Several design options were evaluated for inclusion in the final design of the tailings cell but were rejected for a variety of reasons. The alternatives were considered as a means of complying with the EPA groundwater protection standards that were proposed in September 1987 after the preliminary final RAP was published. The current design incorporates features that are reasonable and prudent to ensure that the EPA standards will be achieved. Other concepts were found to (1) be impractical for the Ambrosia Lake site; (2) be unproven technological applications; or (3) not provide additional assurance of meeting the EPA standards.

Several changes in the cover layers that reduce infiltration were evaluated. These include a sodium amendment (salt) to the radon/infiltration barrier, steeper slopes, a CLAYMAX^{R} membrane, a soil/rock matrix layer, and a vegetated soil cover. Applying additional sodium to the radon/infiltration barrier could create a dispersed soil with a lower hydraulic conductivity. The proposed radon/infiltration barrier will be constructed from compacted weathered Mancos Shale, which has a high content of montmorillonite (a sodium clay). A lower cover infiltration rate would be beneficial to groundwater protection. However, laboratory tests at another site with similar soils demonstrated only small decreases in saturated hydraulic conductivity with large amounts of sodium bentonite added (25 percent). Sodium amended soil could release salts into surrounding soils on groundwater which would be unwanted. Considering the laboratory test results and that a field test of a sodium amendment to uranium mill tailings covers has not been conducted, it is prudent not to include an additional sodium amendment in the cover design.

Steepening the top and sideslopes of the cover was evaluated to determine if it would have the beneficial effect of shedding direct precipitation faster than the current design so that less net infiltration through the tailings may occur. The current design includes 20 percent sideslopes and four percent topslopes. The main drawback of steepening the slopes is that the mean diameter of the rock rip rap and possibly the thickness of the rock layer would need to be increased to compensate for faster flow velocities. This would necessitate a major redesign of the disposal cell, including the buttresses. Upon consideration of the additional design time and material costs weighed against the insignificant increase in protection of the public health, steepened cover slopes have not been included in the cell design.

The use of a CLAYMAX[R] geotextile/bentonite layer was considered because it could restrict infiltration through the cover to approximately 2 x 10^{-9} centimeters per second (cm/s) (the saturated hydraulic conductivity of CLAYMAX[R]). CLAYMAX[R] can only be used on slopes up to 4 percent and therefore cannot be used on side slopes. The current radon/infiltration barrier will have a saturated hydraulic conductivity of approximately 1 x 10^{-7} cm/s. However, the radon/infiltration barrier is expected to remain unsaturated for the design life of 1000 years and should limit infiltration to a rate of 1 x 10^{-7} cm/s to 1 x 10^{-9} cm/s or less. The performance assessment in Section E.3.3 concludes that the current design would ensure that the hazardous constituent concentrations in the leachate from the disposal cell would not exceed existing (i.e., background) concentrations. Incorporating a CLAYMAX[R] layer at the Ambrosia Lake site would necessitate expanding the land area occupied by the cell so that gentler slopes could be used. Using CLAYMAX[R] was not found to be necessary because the current design will meet the requirements for a supplemental EPA groundwater standard for protection of groundwater with limited use.

Alternative surface layers, such as rock with a soil matrix and a vegetated soil cover, were considered for use but were rejected for the reasons explained below. A rock/soil matrix layer with vegetation is less resistant to erosion than the current rock cover, assuming the slope angles remain the same. Slopes could be made less steep so that the soil/rock matrix would meet the criteria for protection from erosion. However, the south part of the tailings pile (the highest area) would have to be relocated to avoid encroaching on the county road by the flattened and extended disposal cell slopes. Alternatively, the county road would have to be relocated to accommodate the much larger disposal cell footprint. Vegetation on the rock soil matrix would probably not persist because of the low precipitation. A vegetated cover was determined to be impractical because of the low annual precipitation (eight inches). Even if a vegetative cover could be satisfactorily established, it probably would not persist over the 1000-year design life of the disposal cell because of the combination of low precipitation and occasional droughts. Again, because the current design can meet the proposed supplemental standard and protects the public, pursuing the change was not necessary.

Further details of the design alternatives that were considered are described in two DOE reports: the Technical Approach Document (1989) and "Remedial Action Planning and Disposal Cell Design" (1989), available through the DOE UMTRA Project Office, Albuquerque Operating Office, Albuquerque, New Mexico.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 PURPOSE

This Remedial Action Plan (RAP) has been developed to serve a dual purpose. It presents the series of activities that is proposed by the U.S. Department of Energy (DOE) to stabilize and control radioactive materials at the inactive Phillips/United Nuclear uranium processing site designated as the Ambrosia Lake site in McKinley County, New Mexico. It also serves to document the concurrence of both the State of New Mexico and the U.S. Nuclear Regulatory Commission (NRC) in the remedial action. This agreement, upon execution by the DOE and the state and concurrence by NRC, becomes Appendix B of the Cooperative Agreement.

1.2 RESPONSIBILITIES

In 1978, Congress passed Public Law 95-604 (PL95-604), the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, expressly finding "that uranium mill tailings located at active and inactive mill operations may pose a potential and significant radiation health hazard to the public . . . ." Title I to the UMTRCA identified sites to be designated for remedial action. On November 9, 1979, Ambrosia Lake was designated as one of those sites.

The UMTRCA charged the U.S. Environmental Protection Agency (EPA) with the responsibility for promulgating remedial action standards for inactive mill sites. The purpose of the standards is to protect public health and safety and the environment from radiological and nonradiological hazards associated with radioactive materials at the inactive sites. The final EPA standards were promulgated January 5, 1983 (48 FR 590), with an effective date of March 7, 1983.

The DOE has been commissioned to select and execute a plan of remedial action that will satisfy the EPA standards and other applicable Federal and state laws. On September 11, 1985, the DOE and the State of New Mexico entered into a cooperative agreement for remedial action at the Ambrosia Lake site. The Federal government will fund 90 percent and the state will fund 10 percent of allowable costs.

All remedial actions must be selected and performed with the concurrence of the NRC. In conformance with UMTRCA, the required NRC concurrence with the selection and performance of proposed remedial actions, and the licensing of long-term surveillance and maintenance of disposal sites, will be to ensure compliance with the standards established by the EPA. The RAP constitutes the initial document in the licensing process. A more detailed listing of the responsibilities of the project participants is included in Section 6.0 of this report.

1.3 SCOPE AND CONTENT

This document has been structured to provide a comprehensive understanding of the remedial action proposed for the Ambrosia Lake site. It includes both criteria and the detailed construction design for the remedial action. An extensive amount of data and supporting information has been generated for this RAP. Pertinent information and data are included in the RAP with references given to the numerous supporting documents.

Attached as part of the RAP are appendices which describe in more detail various important aspects of the remedial action.

Appendix A, Regulatory Compliance, describes in detail the permits necessary for the remedial action and the process for mitigating impacts to archaeological resources.

Appendix B, Engineering Design, consists of the final design specifications and drawings.

Appendix C, Radiological Support Plan, describes the procedures used to characterize the existing radiological conditions at the site, and the procedures to be used to control and verify the results of remedial action.

Appendix D, Site Characterization, describes site geological, geotechnical, hydrological, meteorological, and seismic conditions which affect the design.

Appendix E, Groundwater Protection Strategy, contains the approach and technical discussion of how the stabilized tailings will comply with the EPA groundwater protection standards. The supplemental standards demonstration is included as Attachment A to Appendix E.

Appendix F, Subcontract Documents, contains the final design specifications and drawings.

1.4 COLLATERAL DOCUMENTS

A collateral document for this site is the Environmental Assessment (EA) (DOE, 1987), which contains many of the existing site conditions, the proposed action and alternatives, and the environmental impacts of the proposed action.

The Uranium Mill Tailings Remedial Action (UMTRA) Project staff has prepared the Technical Approach Document (DOE, 1989) which addresses general Project guidelines on the operating procedures, specifications, calculations, schedule and cost estimates, and design constraints to be incorporated in the final design documents. This general guidance, in conjunction with the RAP, serves as the basis or guideline for preparation of the final design documentation for the UMTRA Project sites. It is further intended to provide sufficient criteria for the reader to understand the constraints, procedures, codes, and standards to be used during the design and performance of the remedial actions at the UMTRA Project sites.

Copies of all referenced documents, supporting data, calculations, and design drawings are on file in the U.S. Department of Energy UMTRA Project Office in Albuquerque, New Mexico.

2.0 EPA STANDARDS

2.1 GENERAL

The requirements and considerations for long-term isolation and stabilization of tailings, radon control, cleanup of land and buildings, and protection of water quality have been published in the "Plan for Implementing EPA Standards for UMTRA Sites" (DOE, 1984). That document was used as a guide in the development of this RAP. The following discussion has been extracted from the above-referenced document.

Pursuant to the requirements of the UMTRCA, the EPA promulgated health and environmental standards to govern cleanup, stabilization, and control of residual radioactive materials at inactive uranium mill tailings sites. The promulgated standards establish requirements for long-term stability and radiation protection and provide procedures for ensuring the protection of groundwater quality.

In developing the standards, the EPA determined "that a primary objective for control of tailings should be isolation and stabilization to prevent their misuse by man and dispersal by natural forces such as wind, rain, and flood waters" and that "a second objective should be to reduce radon emissions from tailings piles." A third objective should be "the elimination of significant exposure to gamma radiation from tailings piles" (from 48 FR 594, preamble to Standards for Remedial Action at inactive Uranium Processing Sites, 40 CFR 192.) These objections were based on a determination that the most significant public health risks associated with inactive tailings were posed by exposure to people living and working in structures contaminated by relocated tailings. The EPA further concluded that the potential for groundwater and surface-water contamination should be evaluated on a site-specific basis.

On September 3, 1985, the U.S. Tenth Circuit Court of Appeals remanded the groundwater standards, 40 CFR 192.2(a)(2)-(3). The EPA issued proposed groundwater protection standards for comment on September 24, 1987. Section 2.4, Water-Quality Protection, discusses the DOE plan for implementing the proposed standards until final standards are issued.

The EPA standards are discussed in the following paragraphs and are summarized in Table 2.1.

2.2 LONG-TERM STABILITY

Isolation and stabilization of tailings in order to prevent misuse by man and dispersion by natural forces is the primary objective of the EPA Standards. Accordingly, long-term stability was emphasized in the development and promulgation of the standards. This is consistent with the guidance provided by the legislative history of the UMTRCA, which stresses the importance of avoiding remedial actions which would be effective for only a short period of time and which would require future Congressional consideration.

PART 192 - HEALTH AND ENVIRONMENTAL PROTECTION STANDARDS FOR URANIUM MILL TAILINGS

SUBPART A - Standards for the Control of Residual Radioactive Materials from Inactive Processing Sites

192.02 Standards

Control shall be designed to:

(a) Be effective for up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years, and,

(b) Provide reasonable assurance that releases of radon-222 from residual radioactive material to the atmosphere will not:

(1) Exceed an average release rate of 20 picocuries per square meter per second, or
(2) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter.

SUBPART B - Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites

192.12 Standards

Remedial actions shall be conducted so as to provide reasonable assurance that, as a result of residual radioactive materials from any designated processing site:

(a) The concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than -

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and
(2) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

(b) In any occupied or habitable building -

(1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL, and
(2) The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour.

SUBPART C - Implementation (condensed)

192.20 Guidance for Implementation

Remedial action will be performed with the "concurrence of the Nuclear Regulatory Commission and the full participation of any state that pays part of the cost" and in consultation as appropriate with other government agencies.

192.21 Criteria for Applying Supplemental Standards

The implementing agencies may apply standards in lieu of the standards of Subparts A or B if certain circumstances exist, as defined in 192.21.

192.22 Supplemental Standards

"Federal agencies implementing Subparts A and B may in lieu thereof proceed pursuant to this section with respect to generic or individual situations meeting the eligibility requirements of 192.21."

(a) ". . .the implementing agencies shall select and perform remedial actions that come as close to meeting the otherwise applicable standards as is reasonable under the circumstances."

(b) ". . .remedial actions shall, in addition to satisfying the standards of Subparts A and B, reduce other residual radioactivity to levels that are as low as is reasonably achievable."

(c) "The implementing agencies may make general determinations concerning remedial actions under this Section that will apply to all locations with specified characteristics, or they may make a determination for a specific location. When remedial actions are proposed under this Section for a specific location, the Department of Energy shall inform any private owners and occupants of the affected location and solicit their comments. The Department of Energy shall provide any such comments to the other implementing agencies [and] shall also periodically inform the Environmental Protection Agency of both general and individual determinations under the provisions of this section."

Ref: Federal Register, Volume 48, No. 3, January 5, 1983, 40 CFR Part 192.

TABLE 2.1 EPA STANDARDS

The EPA standard-setting process distinguished "passive controls," such as thick earthen covers, below-ground disposal, rock covers, and massive earth and rock dikes, from "active controls," such as semi-permanent covers, fences, warning signs, and restrictions on land use. Active controls could be expected to need frequent replacement or other major repairs requiring the ongoing appropriation and expenditure of public funds. In setting the standards, the EPA called for designs which rely primarily on passive controls.

The EPA performance standard is framed as a longevity requirement that recognizes the difficulty in predicting very long-term performance with a very high degree of confidence. In establishing the longevity requirement, the EPA concluded that existing knowledge permits the design of control systems that have a good expectation of lasting at least 1000 years. Therefore, a design objective of 1000 years was established to be satisfied whenever reasonably achievable, but in any case a minimum performance period of 200 years must be achieved.

The standard recognizes the need for institutional controls such as custodial maintenance, monitoring, and contingency response measures. In the preamble to the standards, the EPA calls for such controls to be provided as an essential backup to the primary, passive controls.

2.3 RADON EMISSIONS CONTROL

The EPA identified a reduction of radon emissions from tailings piles as the second objective in its standards for the control of tailings. In developing the standards, it considered several alternative approaches and selected an emission limitation as the primary form of the standard. In addition, it established a concentration limit as an alternative form of the standard for use in cases where the DOE determines that the alternative was appropriate.

In establishing the emission limitation for tailings piles, the EPA sought to reduce both the maximum risk to individuals living very near to the sites and the risk to the population as a whole. With regard to individuals very near to disposal sites, the EPA estimates that exposure to radon emissions will be reduced by more than 96 percent. The radon standard of 20 picocuries per square meter per second (pCi/m^2s) on the disposal site or 0.5 picocuries per liter (pCi/l) outside the disposal site will limit the increase in radon concentration attributable to a pile to a small increase above the background radon level near the disposal site. Both standards are design standards with compliance to be determined on the basis of predicted rather than measured emission rates and concentrations. The EPA states that "post-remediation monitoring will not be required to show compliance, but may serve a useful role in determining whether the anticipated performance of the control system is achieved" (from 48 CFR 601, preamble to Standards for Remedial Actions at Inactive Uranium Processing Sites, 40 CFR 192). In establishing the radon standard, the EPA determined that the emission limitation could be achieved by well-designed thick earthen covers and that such control techniques would be compatible with the requirements of the EPA longevity standard.

2.4 WATER-QUALITY PROTECTION

The EPA reviewed available water-quality data from inactive tailings sites and determined that there was little evidence of recent movement of contaminants into groundwater. They also determined that any degradation of groundwater quality should be evaluated in the context of potential beneficial uses of the groundwater as determined by background water quality and the available quantity of groundwater.

Rather than establish specific numerical limitations for contaminant discharges or groundwater quality, the EPA determined that the most appropriate course of action would be to require site-specific analyses of potential future contaminant discharge and a case-by-case evaluation of the significance of such a discharge. The implementation guidelines for the EPA standards call for adequate hydrological surveys at each site to be a basis for determining whether specific water-protection measures should be applied.

Specific site assessments must include monitoring programs sufficient to establish background groundwater quality through one or more upgradient wells and to identify the present movement and extent of contaminant plumes associated with the tailings piles. The water protection standards further call for judgments of the need for restoration or prevention, or both, to be guided by the EPA's hazardous waste management system and relevant state and Federal water-quality criteria. Decisions on specific actions to protect or restore water quality are to be guided by such factors as the technical feasibility of improving the aquifer, the cost of applicable restorative or protective programs, the present and future value of the aquifer as a water source, the availability of alternative water supplies, and the degree to which human exposure is likely to occur.

The UMTRCA (PL95-604, Section 206) requires that the standards promulgated by the EPA "to the maximum extent practicable, be consistent with the requirements of the Solid Waste Disposal Act, as amended." In setting the standard, the EPA determined that the statutory requirement for the NRC to concur with the selection and performance of remedial actions and to issue licenses encompassing "monitoring, maintenance, or emergency measures necessary to protect public health and safety" was consistent with the EPA regulations implementing the Solid Waste Disposal Act (47 CFR 32274, July 26, 1982). Accordingly, the EPA established implementation procedures requiring case-by-case evaluations of potential contamination at sites. Decisions regarding monitoring or remedial actions will be guided by relevant considerations of the hazardous waste management systems.

As mentioned in Section 2.1, the EPA issued proposed groundwater protection standards for comment on September 24, 1987. Prior to promulgation of the final standards, the DOE intends to implement the provisions of Subpart A and C of the proposed standards to the extent reasonably achievable within the UMTRA Project regulatory framework. When the final EPA standards are promulgated, the DOE will re-evaluate its groundwater protection plan and undertake such action as is necessary to ensure that the revised standards are met. The need for and extent of aquifer restoration will be evaluated in a separate decision-making process under the National Environmental Policy Act.

In response to the Court's remand of the original standards, the newly proposed EPA groundwater standards involve:

- o Protection of human health, safety, and the environment.
- o Consideration of radiological and nonradiological hazards.
- o Consistency with the requirements of the Resource Conservation and Recovery Act (RCRA), as amended.
- o General standards applicable to all UMTRA Project sites (i.e., not site-specific as was the case for the remanded standards).

These items are discussed below.

Subpart A (40 CFR 192.01-192.02) consists of the requirements for control of potential contaminant releases to the groundwater at disposal sites. It incorporates the following:

- o A list of hazardous constituents.
- o Maximum concentration limits (MCLs), background limits, or alternate concentration limits (ACLs). The establishment of ACLs must be concurred in by the NRC, be as low as reasonably achievable, and satisfy the water-quality protection considerations.
- o Point of compliance at the downgradient vertical plane of the disposal facility.
- o A liner or equivalent beneath the disposal site if the tailings contain excess water.
- o Monitoring during a post-remedial action period to verify design performance.
- o Corrective action to be initiated within 18 months after monitoring indicates or projects an exceedance of the applicable concentration limits.

Subpart B (40 CFR 192.11-192.12) lists the standards applicable for remediating contaminated groundwater. It incorporates:

- o Cleanup of the listed groundwater constituents to levels specified in Subpart A.
- o Extension of the remedial period to allow for natural flushing if:
  - The groundwater is not, and is not projected to be, a public drinking water source, and

- Institutional controls will effectively protect health and satisfy other beneficial uses, and

- Concentration limits (40 CFR 264.94) will be met in less than 100 years.

Subpart C (40 CFR 192.20-192.22) addresses supplemental standards applicable to Subparts A and B. The supplemental standards provide for alternative actions that come as "close to meeting the otherwise applicable standards as is reasonably achievable." The NRC must concur in the application of supplemental standards. The supplemental standards may be applied if protection of human health and the environment is assured (40 CFR 192.22(d)) and:

- o Remedial actions pose a clear and present threat to workers or the public (192.21(a)).
- o The proposed action would cause more environmental harm than it would prevent (40 CFR 192.21(b)), or
- o Restoration is technically impracticable from an engineering perspective (40 CFR 192.21(f)), or
- o The groundwater is Class III (limited use) (40 CFR 192.21(g)).
- o There is no known remedial action (192.21(e)).

2.5 CLEANUP OF LANDS AND BUILDINGS

The EPA evaluated the risk associated with the dispersion of tailings off the site and concluded that the principal risk to man was the exposure to radon daughter products inside buildings. The EPA therefore stated that the objective of the cleanup of tailings from around existing structures was to achieve an indoor radon daughter concentration (RDC) of less than 0.02 working level (WL). For open lands, the purpose of removing the contamination is to remove the potential for excessive indoor radon daughter concentrations that might arise from new construction on contaminated land. The five picocuries per gram (pCi/g) and 15 pCi/g radium-226 concentration limits for 15-centimeter surface and subsurface layers, respectfully, were considered adequate to limit indoor RDCs to below 0.02 WL. A secondary concern was to limit exposure to people from gamma radiation.

The standard requires that residual radioactive materials be removed from buildings exceeding 0.03 WL. Measures such as sealants, filtration devices, or ventilation devices may be used to provide reasonable assurance of reductions to below 0.02 WL.

3.0 SITE CHARACTERIZATION

Site characterization describes the present condition of the Ambrosia Lake processing site. Appendix D, Site Characterization, contains additional supporting information.

3.1 LOCATION

The inactive Phillips/United Nuclear mill and tailings pile, known as the Ambrosia Lake site, is in McKinley County in northwest New Mexico. The site is 25 road miles north of Grants, New Mexico (Figure 3.1).

3.2 HISTORY

Constructed in 1957, the Phillips Mill was operated by Phillips Petroleum Company from June 1958 until March 1963. Three million tons of uranium ore, averaging 0.23 percent uranium oxide, were processed during the five-year operational period of the mill (FBDU, 1981). Three million tons of tailings were produced during the milling operation. An estimated 396,000 tons of tailings were removed from the site and used as underground mine fill. Following purchase by United Nuclear Corporation, all mining and milling operations were scaled back and milling ceased in April 1963.

All the ore came from nearby mines. Uranium extraction was accomplished at the Phillips Mill using alkaline pressure leach technology (NMEMD, 1979). Portions of the mill were used as a resin ion exchange facility by United Nuclear until late 1982, when all local operations ceased.

3.3 PHYSICAL DESCRIPTION

The site covers 195.6 acres, including the 111-acre tailings pile which contains 2,659,000 cubic yards of tailings. The base of the tailings pile is almost square; the surface of the tailings pile is concave. A perimeter fence has been erected around the tailings pile and windblown area. There are 1,100,000 cubic yards of soil contaminated by windblown material. Details of the extent of windblown contamination are presented in Appendix D, Site Characterization, Section D.3, Radiation Data.

The mill buildings have been demolished and the rubble has been separated into two piles. The contaminated rubble will be placed in the disposal cell during the main construction phase. The less contaminated rubble will be placed in a separate trench to be excavated northeast of the tailings disposal cell.

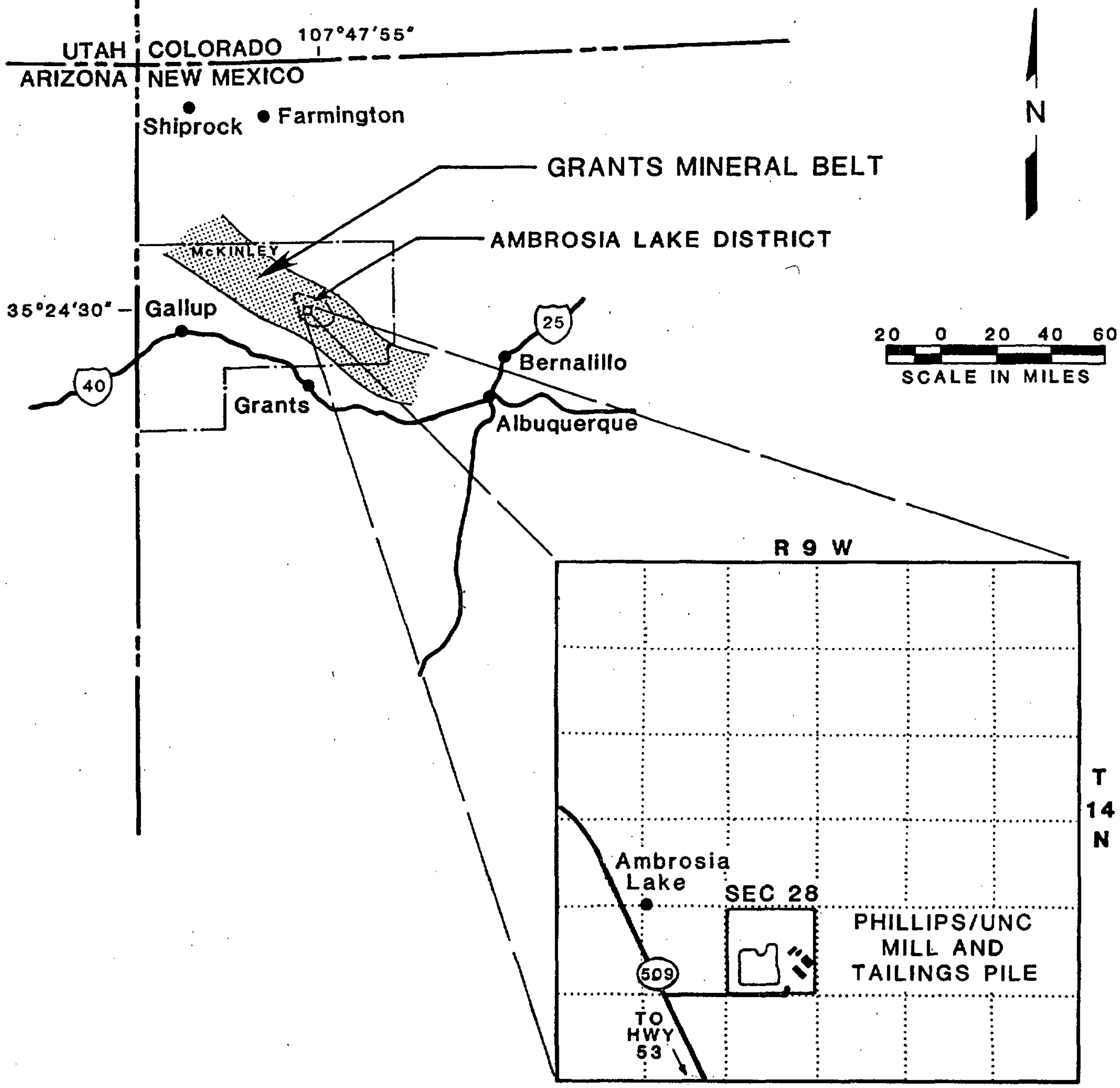


FIGURE 3.1
LOCATION OF AMBROSIA LAKE DESIGNATED SITE

The site is in a valley within the Ambrosia Lake portion of the Grants mineral belt, a major uranium production region. This valley is drained by the Arroyo del Puerto, an ephemeral stream that derives most of its flow from mine-water and mill-water discharge treated elsewhere.

3.4 RADIATION

Radioactive elements occur naturally throughout the earth's air, water, and soil. The concentration of these elements varies greatly throughout the United States. Baseline radioactivity levels in soils typical of the Ambrosia Lake area and not influenced by the tailings pile have been established as 1.2 ± 0.7 pCi/g for radium-226 (Ra-226) (BFEC, 1985). Background concentrations of Ra-226 in soils from areas not influenced by uranium mining and milling averaged 0.57 ± 0.08 pCi/g for Ra-226 (NMEID, 1985).

The average background gamma radiation exposure rate in the Ambrosia Lake region from both terrestrial and cosmic sources, measured at three feet above the ground, is 15.2 microroentgens per hour (microR/hr) with a range of 12.6 to 16.5 microR/hr (BFEC, 1985).

No background radon measurements reflecting current conditions in the vicinity of the Ambrosia Lake designated site are available. However, 24-hour baseline measurements at three locations (0.5 and 0.75 mile north of the tailings pile, and one mile northwest) taken in 1976 averaged 4.3 pCi/l with a range of three to five pCi/l (FBDU, 1981). Natural background radon concentrations in undisturbed areas with similar geologic settings as Ambrosia Lake have been measured by several investigations and averaged 0.19 ± 0.02 pCi/l (NMEID, 1985; Millard and Baggett, 1984).

Soil samples from 106 drill holes on the tailings pile were analyzed by gamma spectroscopy, and computer modeling was used to determine the contaminant distribution and the average Ra-226 concentration of the pile. The resulting average Ra-226 concentration of the tailings was 571 pCi/g (BFEC, 1985). The maximum Ra-226 concentration was 1807 pCi/g.

The soil beneath the tailings pile exceeded the EPA standard of 15 pCi/g Ra-226 to an average depth of approximately 4.75 feet.

Using Schiager's estimate (Schiager, 1974) of 2.5 (microR/hr)/(pCi/g), and the average tailings pile Ra-226 concentration of 571 pCi/g, the gamma exposure rate for the pile would be 1428 microR/hr. Based on an aerial survey, exposure rates ranged from 350 to 1500 microR/hr (EG&G, 1981).

The radon flux source term from the tailings pile was calculated using the RAECOM model (NRC, 1984), resulting in an estimated annual average radon flux of 556 pCi/m^{2}s under existing conditions.

Field data (Haywood et al., 1980; BFEC, 1985) indicate that extensive transport of gamma-emitting contamination by wind or water erosion has occurred into the area surrounding the tailings pile. Contamination sources include residual ores and wastes from mining, and ponded slimes from mine dewatering. Analysis of the Ra-226/uranium-238 ratio in soil samples was used to delineate areas contaminated by ore from areas contaminated by windblown tailings. Five-hundred and seventy acres contaminated by windblown tailings and ore stock piles will require remedial action. Concentrations of Ra-226 ranged from five pCi/g to 4058 pCi/g.

3.5 GEOLOGY, GEOMORPHOLOGY, AND SEISMICITY

3.5.1 Introduction

Geologic, geomorphic, and seismic investigations were conducted in the area and region of the Ambrosia Lake site. Detailed findings of the studies are presented in Section D.4, Appendix D, Site Characterization. Geologic hazards with the potential to affect long-term pile stability have been identified and evaluated during UMTRA Project geologic investigations.

The investigations performed for the Ambrosia Lake designated site included:

- Compilation and analysis of previous geologic work.
- Review of earthquake data using the National Geophysical Data Center (NGDC) earthquake listing and other seismic net catalogs.
- Analysis of site-specific UMTRA Project geologic data.
- Evaluation of existing remote sensing imagery.
- Low-sun-angle aerial reconnaissance.
- Ground reconnaissance and mapping.

3.5.2 Geologic setting

The Ambrosia Lake site is in northwestern New Mexico, within the Navajo section of the Colorado Plateau physiographic province (Figure 3.2). Terrain in this section of the plateau is generally moderate to low relief, and is composed primarily of flat-topped, gently sloping cuestas, broad steep-scarped mesas, low-gradient pediment and fan surfaces, deeply incised canyons and arroyos, and strike valleys. The Mt. Taylor volcanic complex dominates the physiography within the 40-mile (65-kilometer) study region, rising to more than 4000 feet above surrounding the topography. Vast basalt flows and cinder cone fields cover large areas west and south of the Ambrosia Lake site.

Cenozoic tectonic and erosional processes have exposed rocks of Precambrian through Late Quaternary age in the study region (Figure 3.3). With the exception of Quaternary basalt flows,

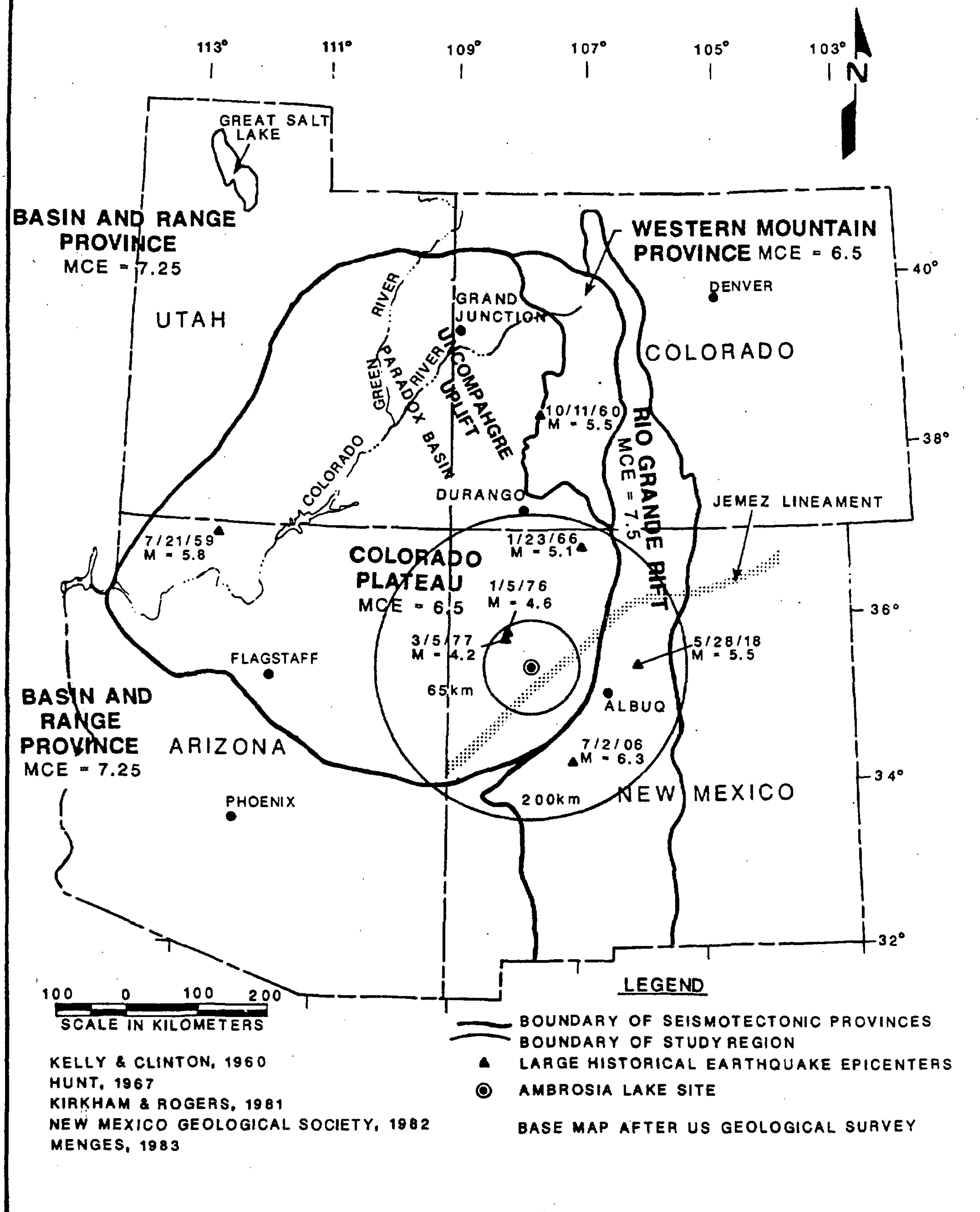


FIGURE 3.2
REGIONAL SEISMOTECTONIC SETTING AND STUDY REGION MAP

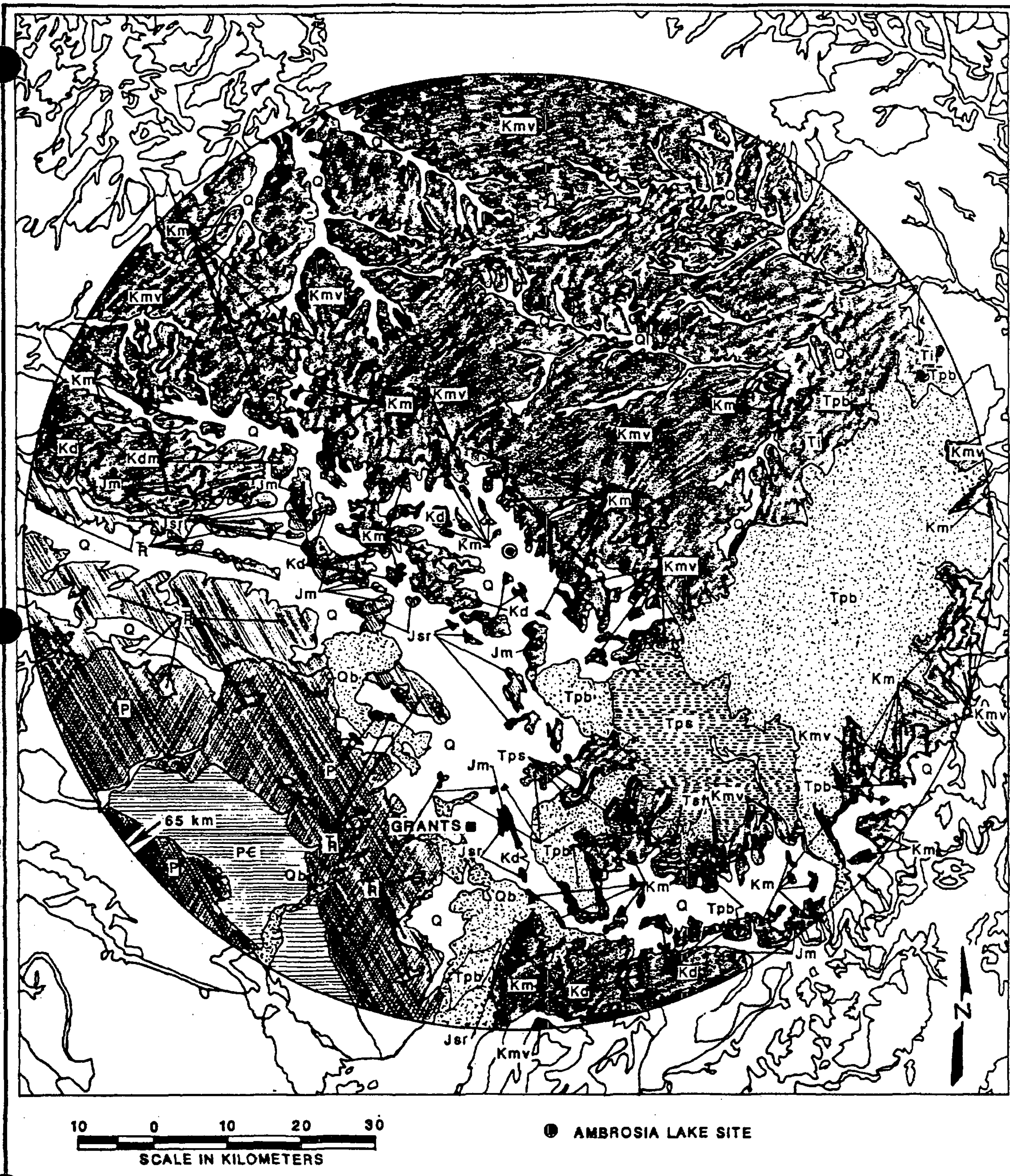


FIGURE 3.3
BEDROCK GEOLOGY OF THE AMBROSIA LAKE STUDY REGION
(MODIFIED AFTER BALDRIDGE, et al, 1983)

LEGEND

Q QUATERNARY (undivided): Fluvial sediments of gravel, sand and clay; alluvial fan deposits; colluvium, soils, landslides. Locally includes units mapped as Pliocene-Pleistocene.

Qb QUATERNARY MAFIC VOLCANIC ROCKS ($\leq$ 1.8 m.y.): Tholeiite, basanite, alkali olivine basalt, and related alkalic basaltic rocks.

Tpb PLIOCENE MAFIC VOLCANIC ROCKS (1.8 - 5.0 m.y.): Tholeiite, alkali olivine basalt, basanite, and related alkalic basaltic rocks.

Tps PLIOCENE INTERMEDIATE AND SILICIC VOLCANIC ROCKS (1.8 - 5.0 m.y.): Basaltic andesite, alkali andesite, quartz latite, dacite, rhyolite, trachyte.

Kl UPPER CRETACEOUS: Shale, with minor sandstone and siltstone. Lewis Shale in northwestern New Mexico.

Kmv UPPER CRETACEOUS: Sandstone, shale, carbonaceous shale, and coal. Mesa Verde Group (Menefee Formation, Gallup Sandstone, Crevasse Canyon Formation, Point Lookout Sandstone).

Km UPPER CRETACEOUS: Shale with minor sandstone and limestone. Mancos Shale.

Kdm LOWER TO UPPER CRETACEOUS: Undifferentiated Mancos Shale and Dakota Sandstone in northwestern New Mexico.

Kd LOWER TO UPPER CRETACEOUS: Dakota Sandstone.

Jm UPPER JURASSIC: Sandstone, mudstone, conglomerate, with nodular chert. Morrison Formation.

Jsr MIDDLE JURASSIC: Limestone, shale, bituminous shale, mudstone and limestone. San Raphael Group (Bluff Formation, Summerville Formation, Todilto Formation, Entrada Sandstone.

Tr TRIASSIC: Shale, siltstone, sandstone, conglomerate, limestone. Wingate Formation, Chinle Formation.

P PERMIAN: Sandstone, siltstone, shale, limestone, gypsum, conglomeratic sandstone, orthoquartzitic sandstone. Glorieta Formation, San Andres Limestone.

P€ PRECAMBRIAN: Phyllite, quartz schist, metaquartzite, gneiss, granite, and metavolcanic rocks. In central New Mexico also olivine gabbro, amphibolite, and granite pegmatite.

FIGURE 3.3 (CONCLUDED)
BEDROCK GEOLOGY OF THE AMBROSIA LAKE STUDY REGION

Precambrian igneous and Paleozoic sedimentary units crop out south of the tailings site in the vicinity of the Zuni Uplift. Progressively younger strata are exposed in the central and northern portions of the study area, terminating with deltaic deposits of the upper Cretaceous Fruitland Formation. Extrusive volcanic rocks of primarily Miocene and Pliocene age constitute the Mt. Taylor and Mesa Chivato physiographic features east and northeast of the existing tailings pile.

The Ambrosia Lake site lies in a northwest-trending strike valley cut into the upper Cretaceous Mancos Shale. Approximately 3000 feet (1000 meters) of Permian to Cretaceous age clastic sedimentary strata underlie the site (Figure 3.4). The sedimentary section dips northeastward at two degrees, and forms a regional homocline of the southern San Juan Basin referred to as the Chaco Slope.

Wind erosion and dispersion of the mill tailings over the past 22 years has resulted in the formation of dunes immediately east of the existing pile. Numerous locations in the Ambrosia Lake area contain localized dune fields and reflect the significance of eolian activity. The embankment design contains protective layers of earthen and rock material that will prevent future wind erosion of tailings. Pile armoring and other design features are discussed in Section 4.0, Site Design.

Gullying processes are active throughout the upland sideslope areas of the Ambrosia Lake valley. However, gullying does not have the potential to affect the tailings embankment within the proposed 1000-year design life due to the design and location of the stabilized pile. Established drainages north, south, and east of the site exhibit no evidence of active lateral erosion or headcutting.

As discussed in Section 4.0, tectonic faults are abundant in the study region and reflect multiple episodes of deformation. Most of the structures are of Laramide age, exhibiting north and northeast trends. Displacement is most commonly down to the east and on the order of a few tens of feet. In addition to the regional uplifts and monoclinal elements forming the southern margin of the San Juan Basin, numerous small-scale domes, anticlines, and synclines locally deform the otherwise uniform regional bedding orientation. Vertical displacement of the Laramide age local structures is generally less than 500 feet.

Unconsolidated alluvial and eolian deposits of late Quaternary age mantle extensive low-lying portions of the study region and site vicinity (Figure 3.5). Within the Ambrosia Lake valley, thicknesses of alluvium exceed 100 feet near Arroyo del Puerto, which is one mile southwest of the site. Valley sideslope alluvial sediments in the immediate site vicinity range in depth from five to 55 feet.

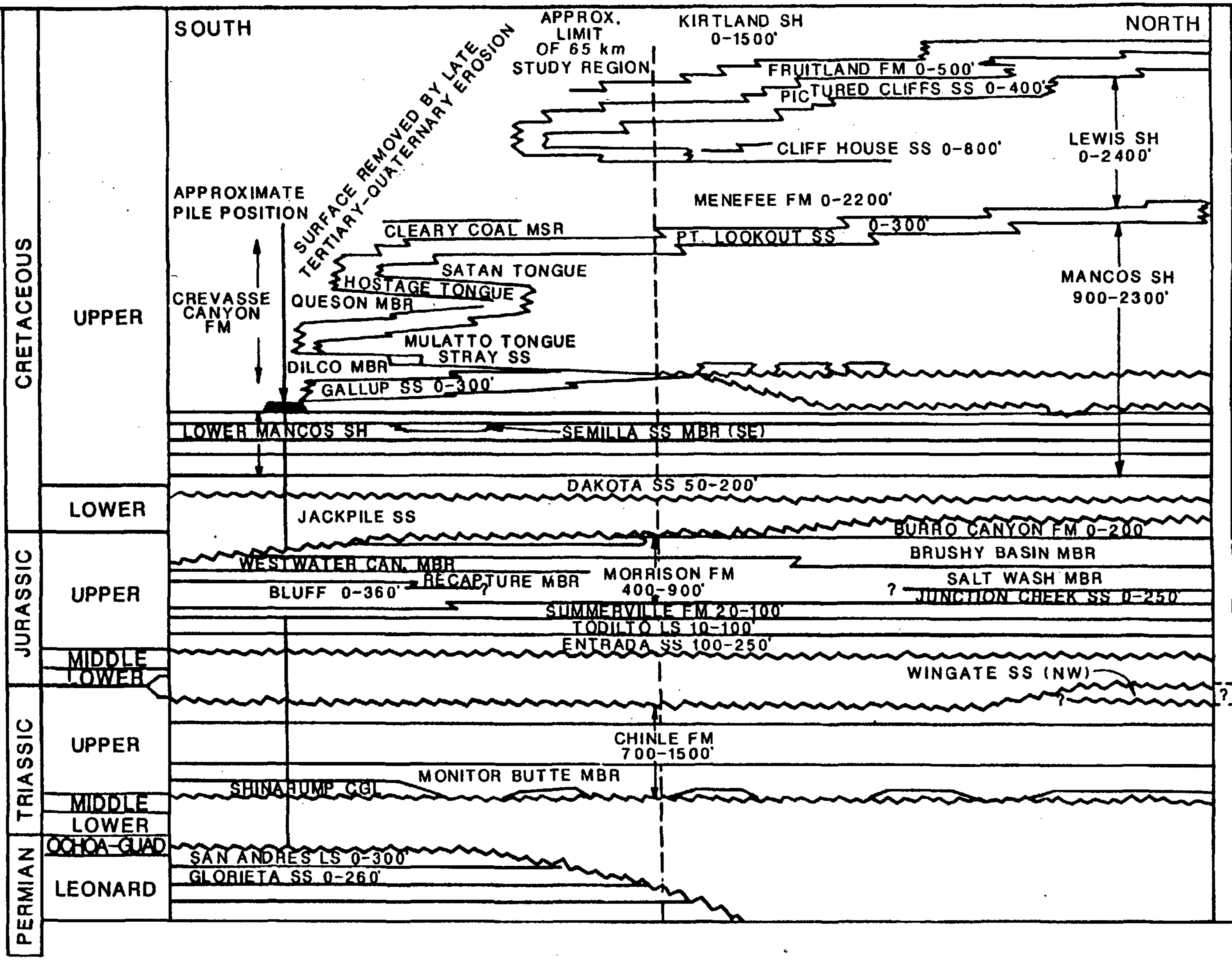


FIGURE 3.4
SOUTH TO NORTH STRATIGRAPHIC SECTION OF THE SAN JUAN BASIN
(MODIFIED FROM MOLENAAR, 1977)

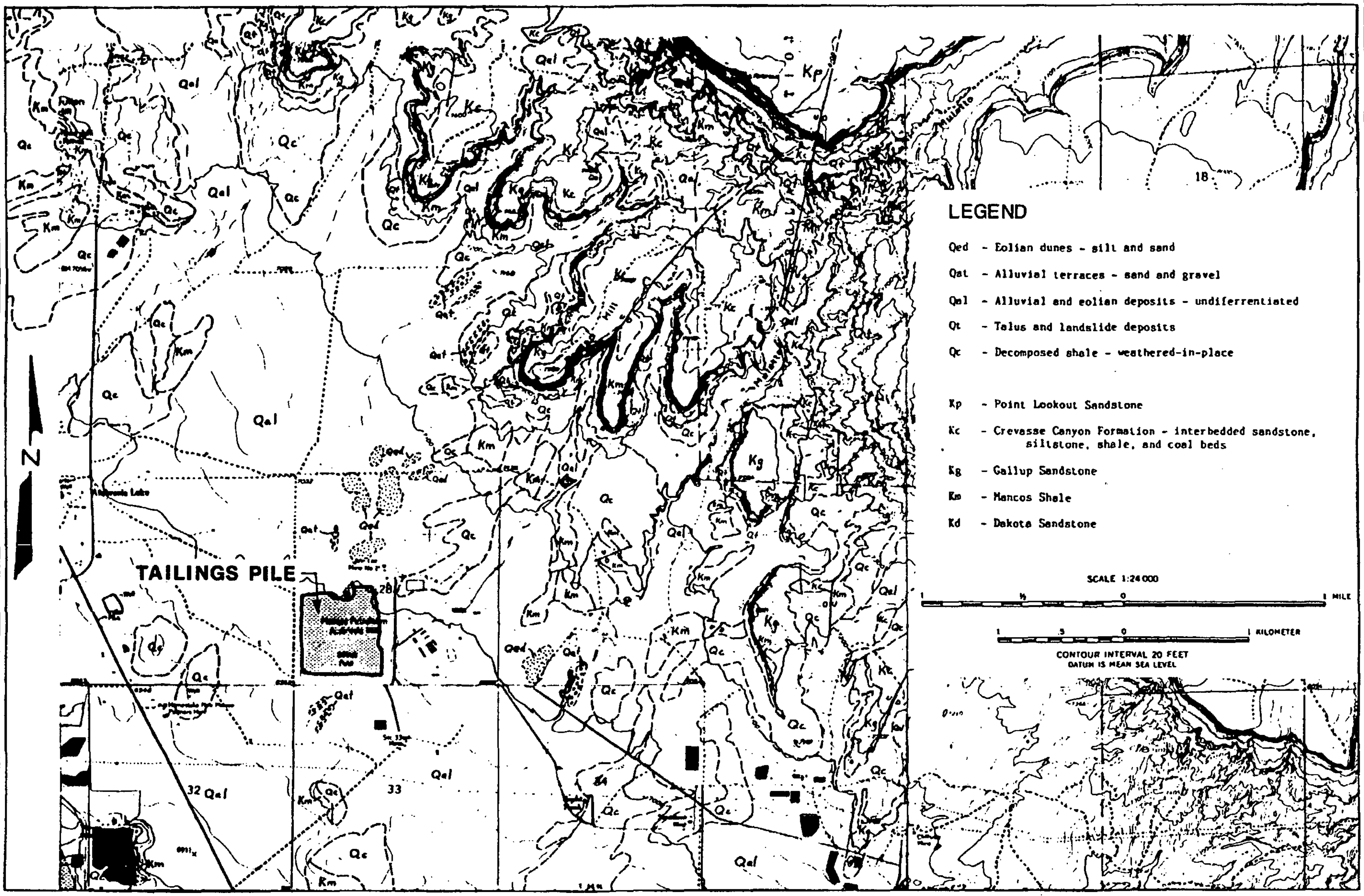


FIGURE 3.5
SURFICIAL GEOLOGIC MAP OF THE AMBROSIA LAKE SITE VICINITY (MODIFIED FROM SANTOS AND THADEN, 1966)

3.5.3 Geomorphology

Geomorphic processes operating in the study region were identified primarily through an analysis of regional and local landforms. A subsequent evaluation of active geomorphic processes modifying the present-day landscape was conducted.

The current geomorphic regime in the Ambrosia Lake region is dominated by fluvial and eolian erosion processes. Present geomorphic conditions have persisted in the area for the past few thousand years and are not expected to change significantly during the 1000-year embankment design life. The proposed stabilized pile has been designed to preclude future disturbance of tailings by fluvial geomorphic processes, including flooding and on-pile rill and gully development.

Mass wasting and natural slope failure processes are not active in the vicinity of the Ambrosia Lake site. Potential geomorphic processes which have been eliminated as hazards with respect to long-term pile integrity are:

- Landslides.
- Debris flows.
- Mudflows.
- Rock falls.
- Soil creep.

Mining-induced surface subsidence has occurred at several locations in the Ambrosia Lake valley. The failure of strata overlying mine voids in adjacent Section 27 has resulted in the formation of an elliptical depression 800 feet west of the edge of the existing tailings pile. Mining passages that are present beneath the southwestern edge of the tailings pile are of considerably smaller dimension and reflect a different mining method than those causing the Ambrosia Lake subsidence zones. Engineering and geologic analyses presented in Section D.4.5.4 of Appendix D, Site Characterization, and in calculations supporting Appendix B, Engineering Design, conclude that a collapse of the strata overlying these voids would not jeopardize the integrity of the stabilized embankment.

3.5.4 Seismicity

An area within a 120-mile (200-kilometer) radius of the Ambrosia Lake site was examined during the seismic investigation. The seismotectonic setting of the study region includes portions of the Colorado Plateau, Basin and Range, Rio Grande Rift, Western Mountains, and Great Plains seismotectonic provinces.

The Colorado Plateau province, which contains the designated site (Figure 3.6), consists of a stable interior flanked on the western, southern, and eastern sides by tectonic transition zones. In comparison to the stable interior, the transition zones exhibit elevated levels of seismic activity and contain structures that

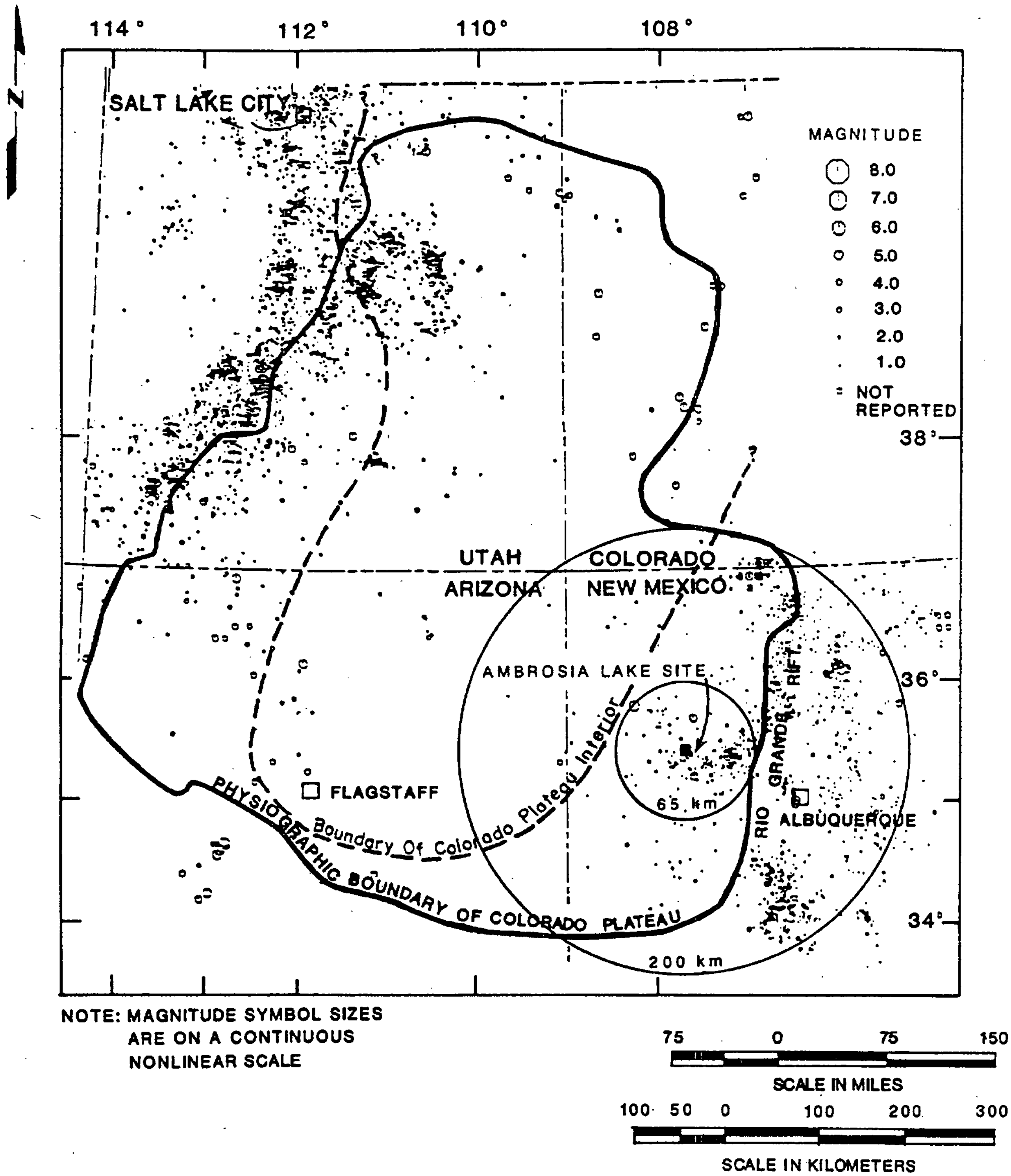


FIGURE 3.6

SEISMICITY MAP OF THE COLORADO PLATEAU AND TRANSITION ZONES 1962 TO 1980 (MODIFIED FROM ZOBACK AND ZOBACK, 1980; WONG, 1984)

reflect the stress fields dominating adjacent provinces. The Ambrosia Lake study region constitutes a portion of the transition zone that separates the Colorado Plateau interior and the Rio Grande Rift.

The largest historical earthquake in the 120-mile study radius occurred in 1906, 105 miles (165 kilometers) southeast of the existing tailings pile in the Rio Grande Rift. Intensity effects indicate that the event had a 6.3 Richter magnitude. Smaller shocks of 4.6 and 4.2 local magnitude occurred in 1976 and 1977 near Crownpoint, New Mexico, 36 miles (58 kilometers) and 34 miles (54 kilometers) northwest of the site, respectively. The vast majority of the seismic events recorded in the study region are epicentered in the Mt. Taylor and Mesa Chivato volcanic complex. No relationship can be drawn between the dominantly microseismic data and known tectonic faults in the volcanic complex.

The Ambrosia Lake seismic study in each of the pertinent seismotectonic provinces included:

- o An evaluation of major fault systems and known capable or potentially capable structures which could possibly influence pile design.
- o An analysis of on-site acceleration effects due to the Maximum Credible Earthquake value as obtained from published seismic studies. The event was assumed to occur at the closest approach of a province to the site.
- o An examination of the seismic character of the site through the review and interpretation of historical earthquake records and journal articles related to provincial seismicity.

Structures capable of producing large magnitude earthquakes exist in seismotectonic provinces bordering the Colorado Plateau. Predicted on-site accelerations resulting from the occurrence of large earthquakes in adjacent provinces will not affect the stabilized pile.

No late Quaternary deposits in the area of investigation are tectonically offset; hence, it is concluded that all faults in the 40-mile radius surrounding the site are noncapable as defined in 10 CFR 100. The lack of capable structures in the study area requires that a floating earthquake be used to establish seismic design parameters for the proposed embankment. Such an event is independent of known tectonic structure and could occur anywhere within the Colorado Plateau seismotectonic province. A review of historical Colorado Plateau seismicity and of documented ground breakage associated with large magnitude earthquakes in the western United States prompted the specification of 6.2 local magnitude for the plateau floating earthquake. The epicenter of the floating earthquake is assumed to occur at a nine-mile

(15-kilometer) distance from the site. The on-site, nonamplified, free-field Peak Horizontal Acceleration resulting from this event is 0.21g. Focal plane solutions for events in the Ambrosia Lake region suggest that the source mechanism for the design earthquake would be controlled by the prevailing northeast-southwest directed extensional stress field.

There is no potential for fault rupture at or near the Ambrosia Lake site based on intense geologic field studies conducted in the area. The tectonically induced collapse of mine workings is a remote possibility; however, its occurrence would not threaten the structural integrity of the tailings embankment (Section D.4.5.4 of Appendix D, Site Characterization).

3.5.5 Volcanism

Extrusive volcanic rocks constitute a significant portion of the southern and eastern study area bedrock exposures (Figure 3.3). The potential for eruptions and surface flows northeast, east, and south of the site vicinity is high as evidenced by recurrent late Cenozoic volcanism in the Mt. Taylor volcanic field. The youngest basalt flows in the study region are between 800 and 1200 years old. Surface flows emanating from the Mt. Taylor area would need to greatly exceed the physical proportions of typical Quaternary flows in the study region in order to jeopardize the structural integrity of the proposed embankment. Ash falls resulting from the occurrence of explosive volcanism within the Mt. Taylor volcanic complex would not impact site stability.

3.5.6 Mineral resources

Low-grade uranium, vanadium, and molybdenum ores exist in strata underlying the site vicinity. Extraction of these reserves is presently uneconomical except by mine water recovery. With the exception of minor quantities of sand and gravel building aggregates and mine water recovery of uranium, there are no recoverable metallic or nonmetallic resources in the Ambrosia Lake area. Continued strip mining of coal reserves north of the site area will not impact pile stability because of the distance involved. Resource exploitation beneath the disposal site will be prohibited to ensure the long-term integrity of the tailings embankment.

3.6 GEOTECHNICAL

The definition of geotechnical conditions at the processing site included the following work:

- Definition of stratigraphy within the pile and foundations.

- o Development of design parameters for both in situ and remolded borrow materials.

- o Completion of field and laboratory tests.

The site and surrounding soils were characterized by drilling 281 borings, drilling 126 piezocone holes, and digging 25 test pits. Figures 3.7 through 3.11 show the locations of the boreholes, piezocone soundings, on-pile hydrological borings, and test pits that were sampled for geotechnical purposes. Of the 281 borings, 209 were made during previous studies. (MSRD, 1982; FBDU, 1981.) (Figure 3.7.) Bendix (BFEC, 1985) drilled and geophysically logged 43 holes to determine the depths of subsurface contamination. During 1985, DOE contractors drilled and logged 72 boreholes and pushed 126 piezocone-sounding holes on the pile, drilled 26 holes off the pile for monitor wells, and dug test pits in the radon/infiltration barrier borrow area. The lithology logs for the various characterization efforts were presented in Addendum D3 of Appendix D, Site Characterization in the May 1987 Preliminary Field RAP. These data have not been reproduced in this issue of the RAP.

3.6.1 Foundation soils

The soils underlying the site generally consist of alluvium and weathered Mancos Shale as shown in Figures 3.12 through 3.15. These figures show the cross sections and general zones for the different material types as represented in the actual pile. In order to see some of the small layers in the embankment, an exaggerated vertical scale was used in the cross sections. Figure 3.16 shows the structural contour map for the top of bedrock under the tailings embankment. The data used to construct the cross sections and structural contour maps come from piezocone soundings, geotechnical borings, and logs from the hydrologic monitor wells. The bedrock elevations shown on the cross sections are based on the bedrock contour map. The alluvium is generally thickest on the western portion of the pile, while the weathered Mancos Shale is thickest under the eastern portion of the pile. The alluvium consists of clayey or silty sands with some very sandy clays. The origin of these materials appears to be primarily from the Crevasse Canyon Formation and secondarily from the Mancos Shale.

The weathered Mancos Shale is thickest on the eastern portion of the pile, while on the southwest side of the pile the thickness of the weathered shale reduces to zero. Toward the western side of the pile it appears that the weathered shale may have been eroded away before deposition of the alluvium.

The contact between the alluvium and weathered Mancos Shale was difficult to locate because the alluvium is a clayey or silty sand while the weathered Mancos Shale is often a sandy clay. Near the east side of the pile, the Mancos Shale is at a fairly shallow depth and the tailings rest directly over the weathered Mancos Shale. The alluvium in this area may have been used for construction of the starter dike or it may simply have eroded

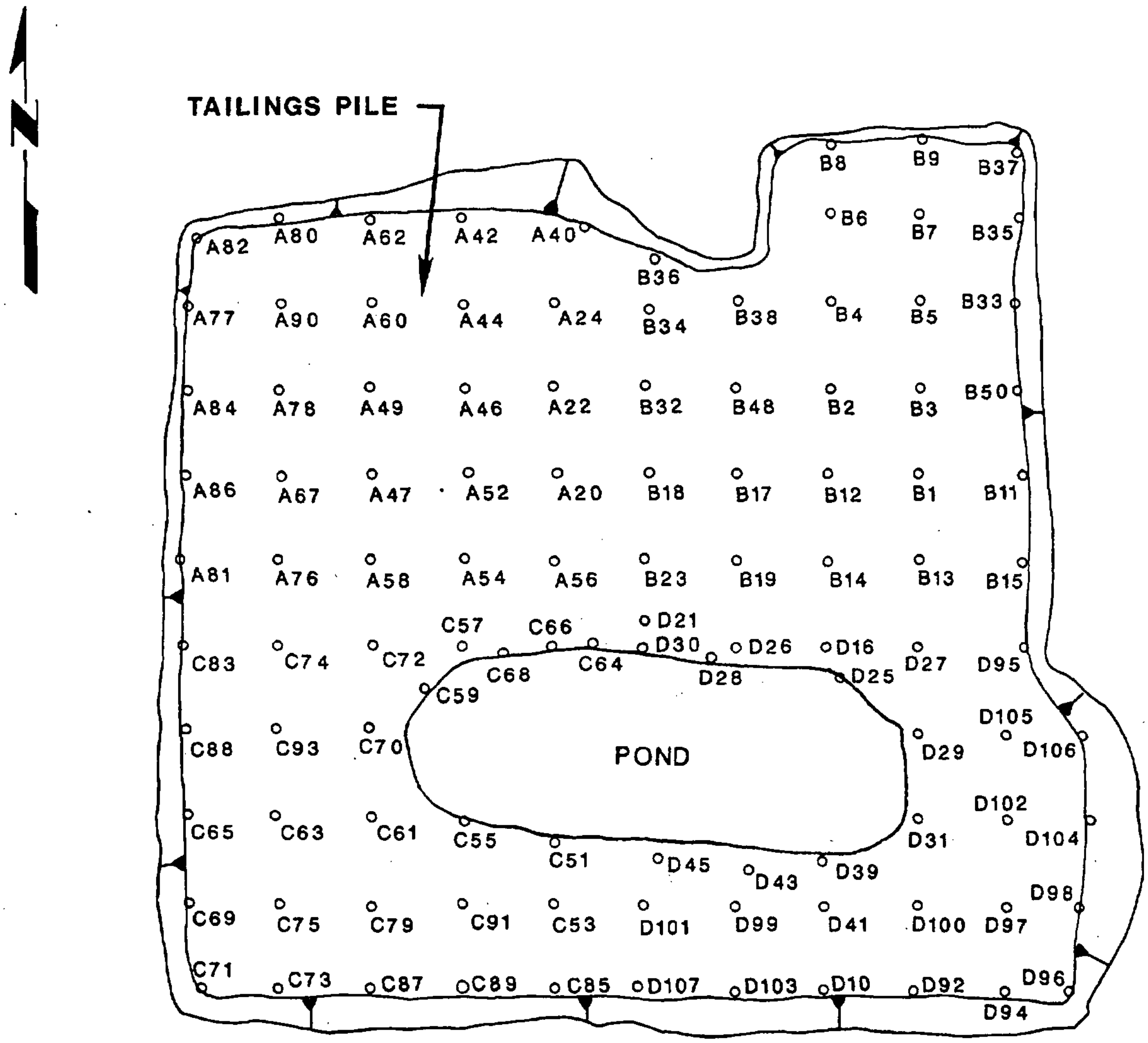


FIGURE 3.7
BOREHOLE LOCATIONS FROM PREVIOUS STUDIES

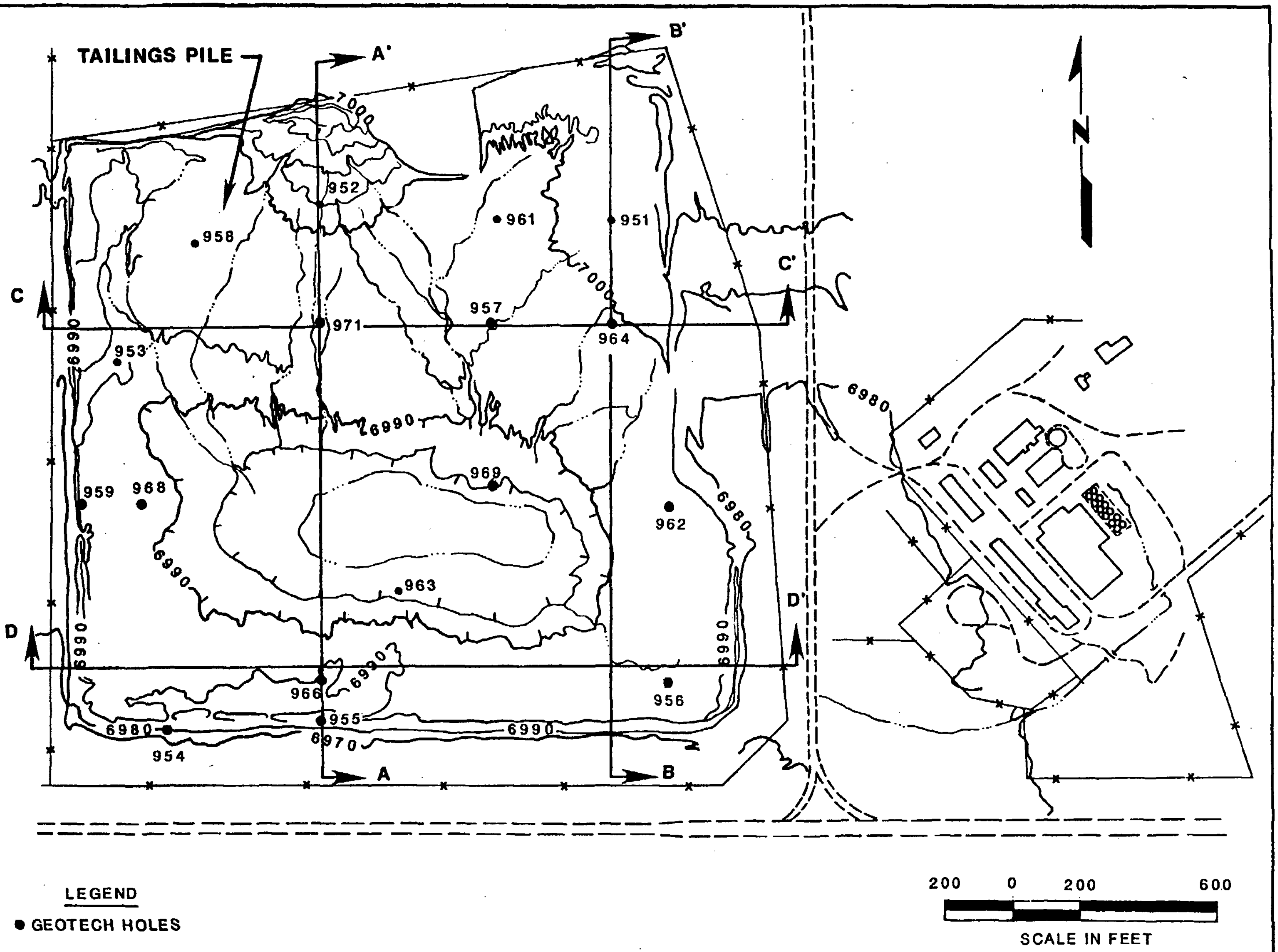


FIGURE 3.8 ON-PILE GEOTECHNICAL BOREHOLE LOCATIONS AT AMBROSIA LAKE

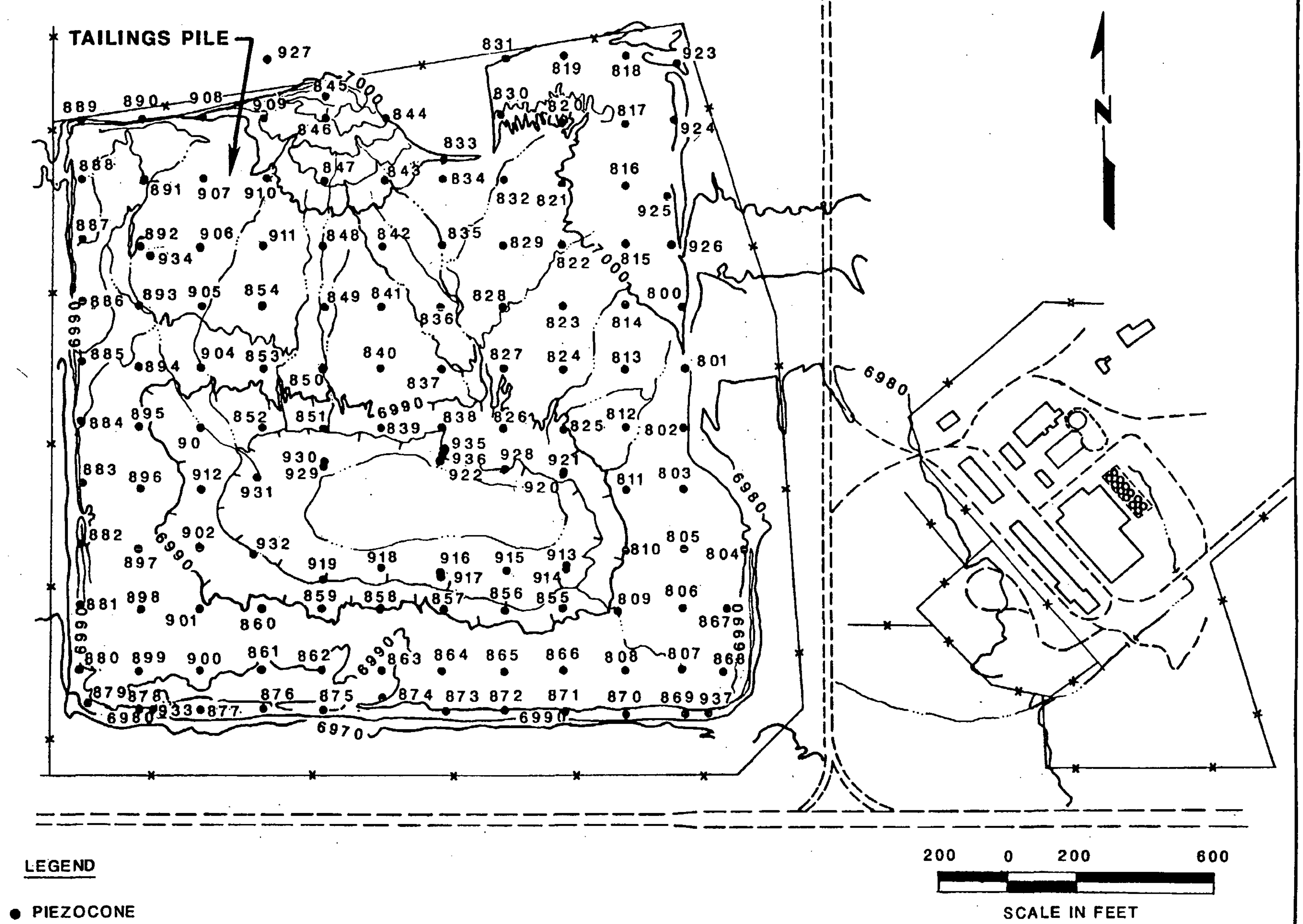


FIGURE 3.9 ON-PILE PIEZOCONE SOUNDING LOCATIONS AT AMBROSIA LAKE

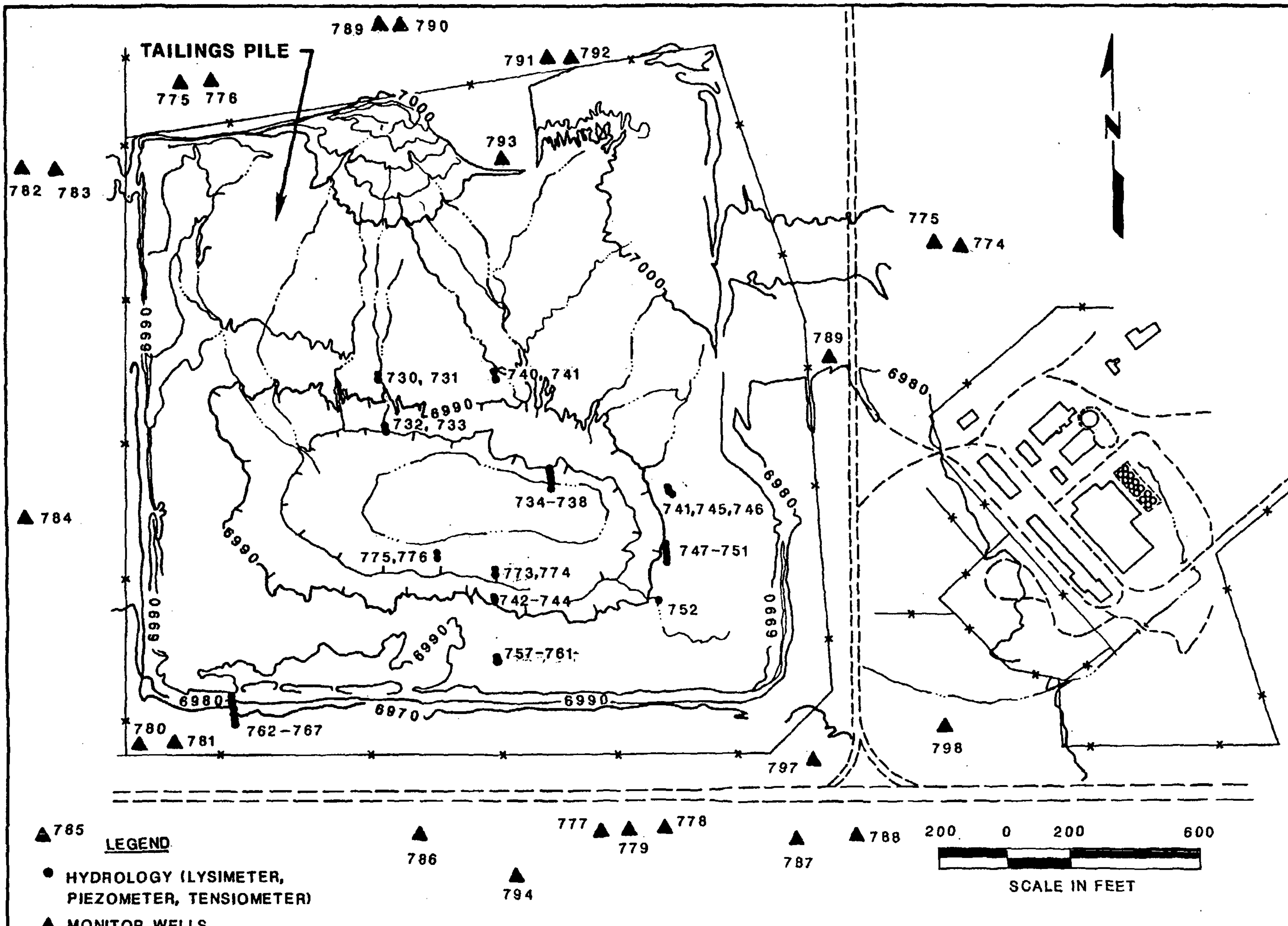
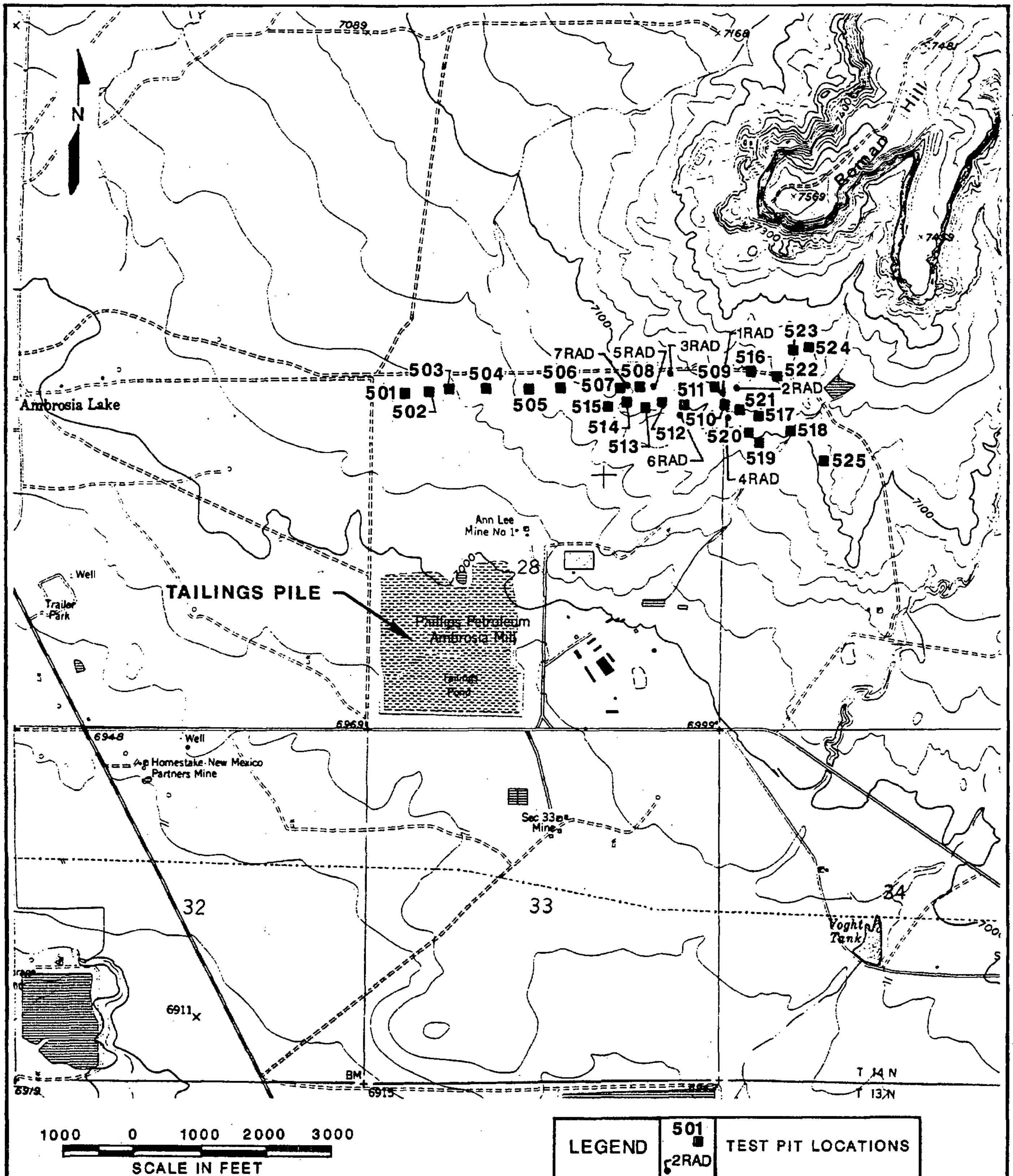


FIGURE 3.10 HYDROLOGY BOREHOLE LOCATIONS AT AMBROSIA LAKE



REF: AMBROSIA LAKE USGS 7.5 MIN.

FIGURE 3.11
TEST PIT LOCATIONS FOR RADON BARRIER MATERIAL

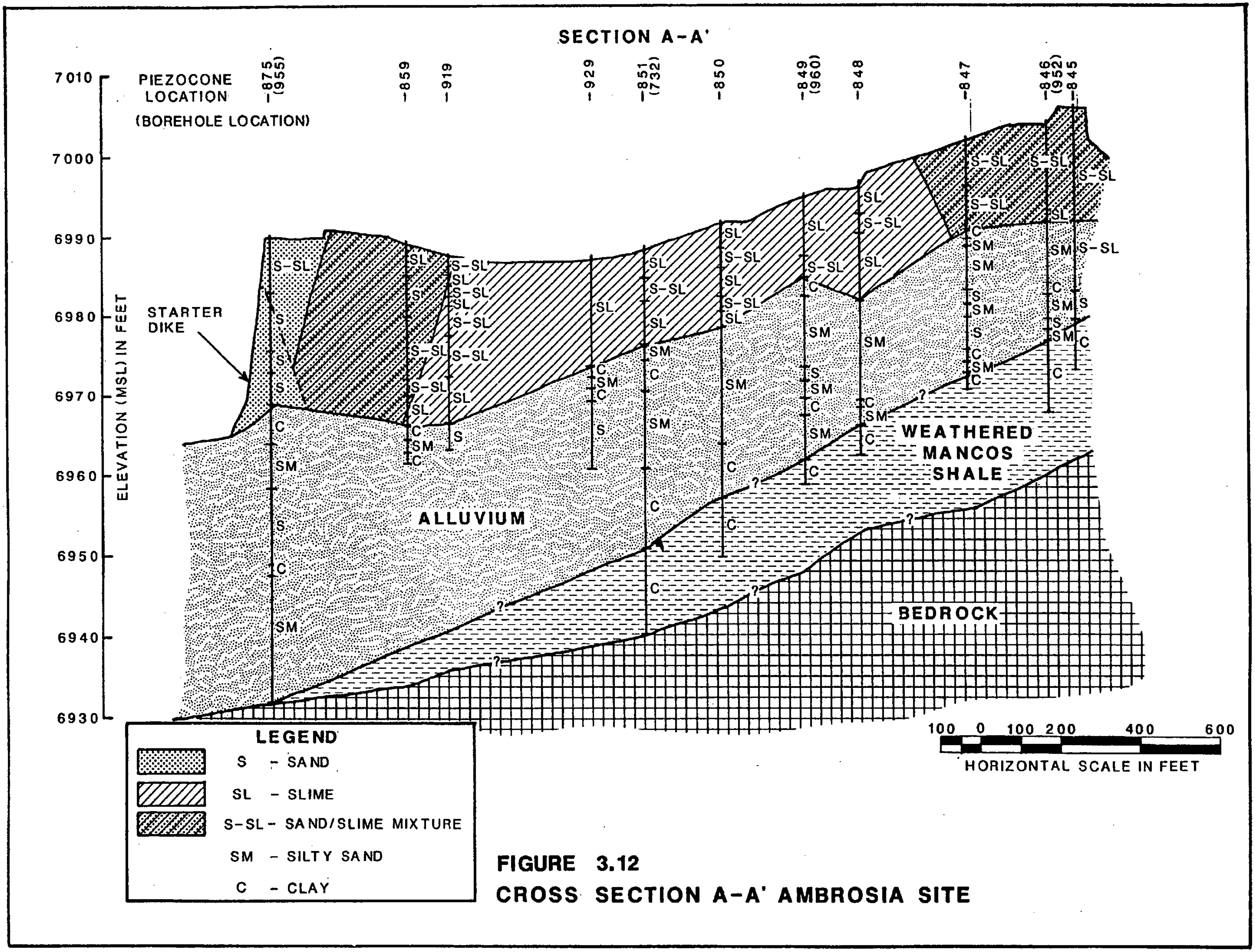


FIGURE 3.12
CROSS SECTION A-A' AMBROSIA SITE

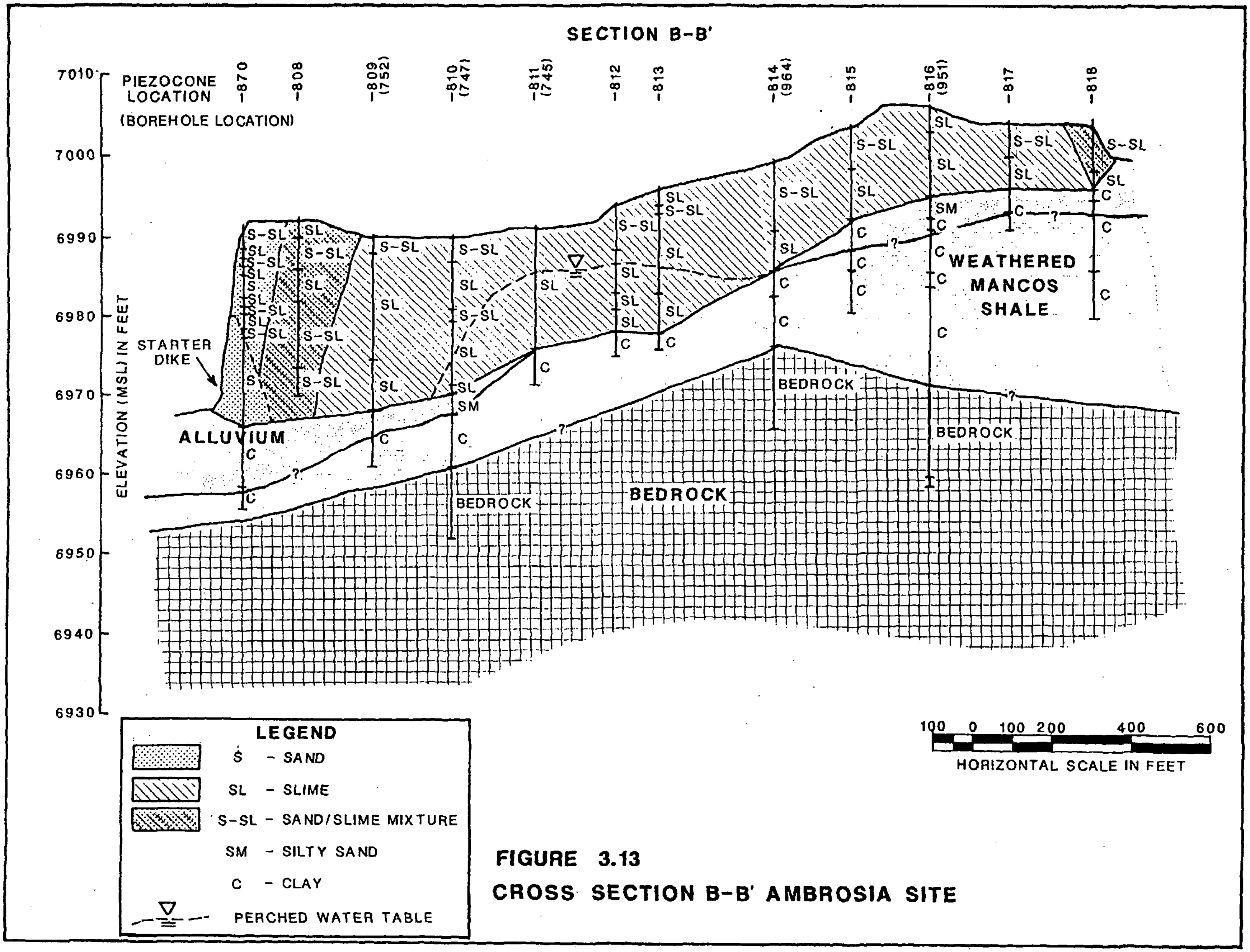


FIGURE 3.13
CROSS SECTION B-B' AMBROSIA SITE

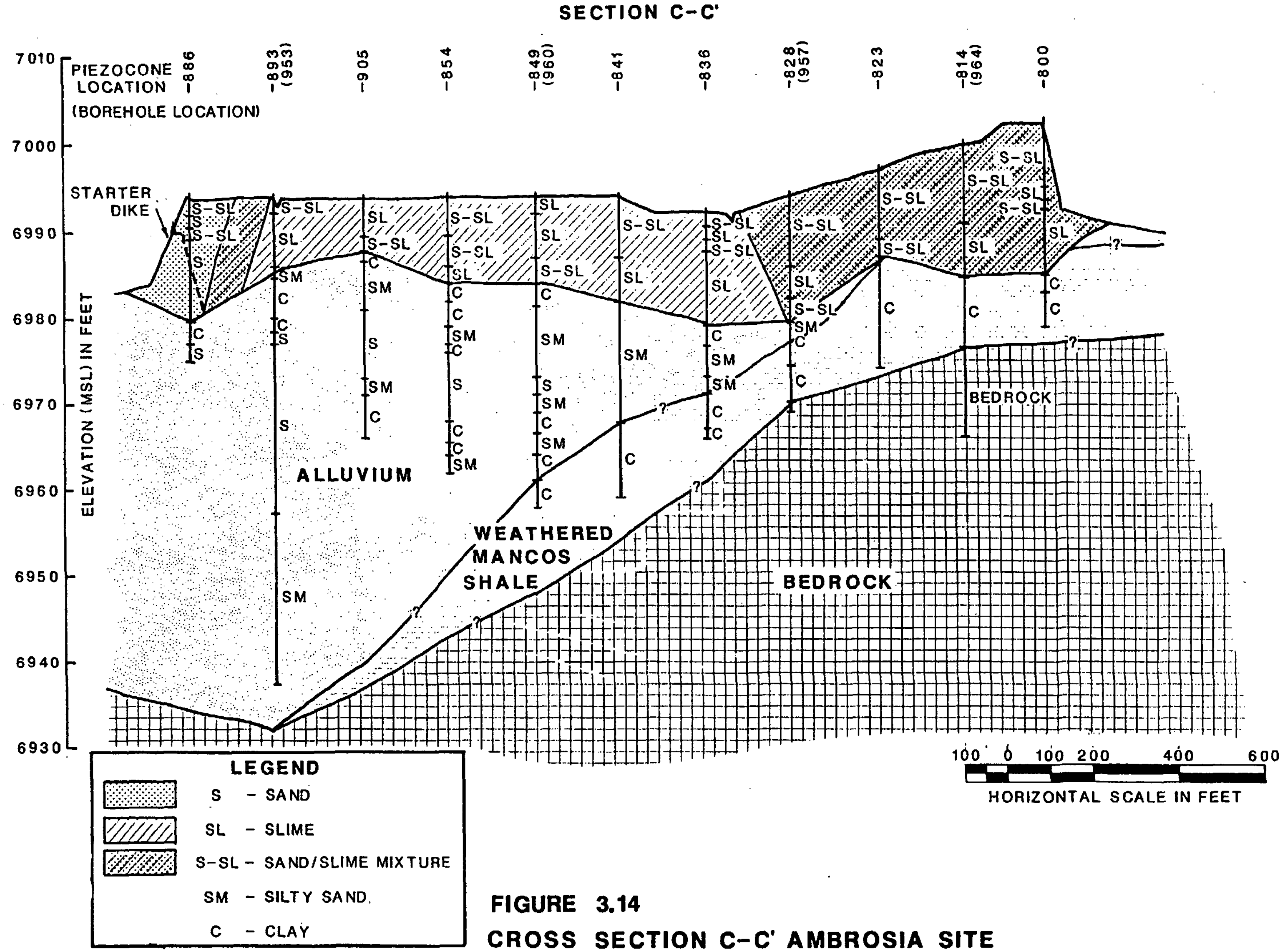


FIGURE 3.14
CROSS SECTION C-C' AMBROSIA SITE

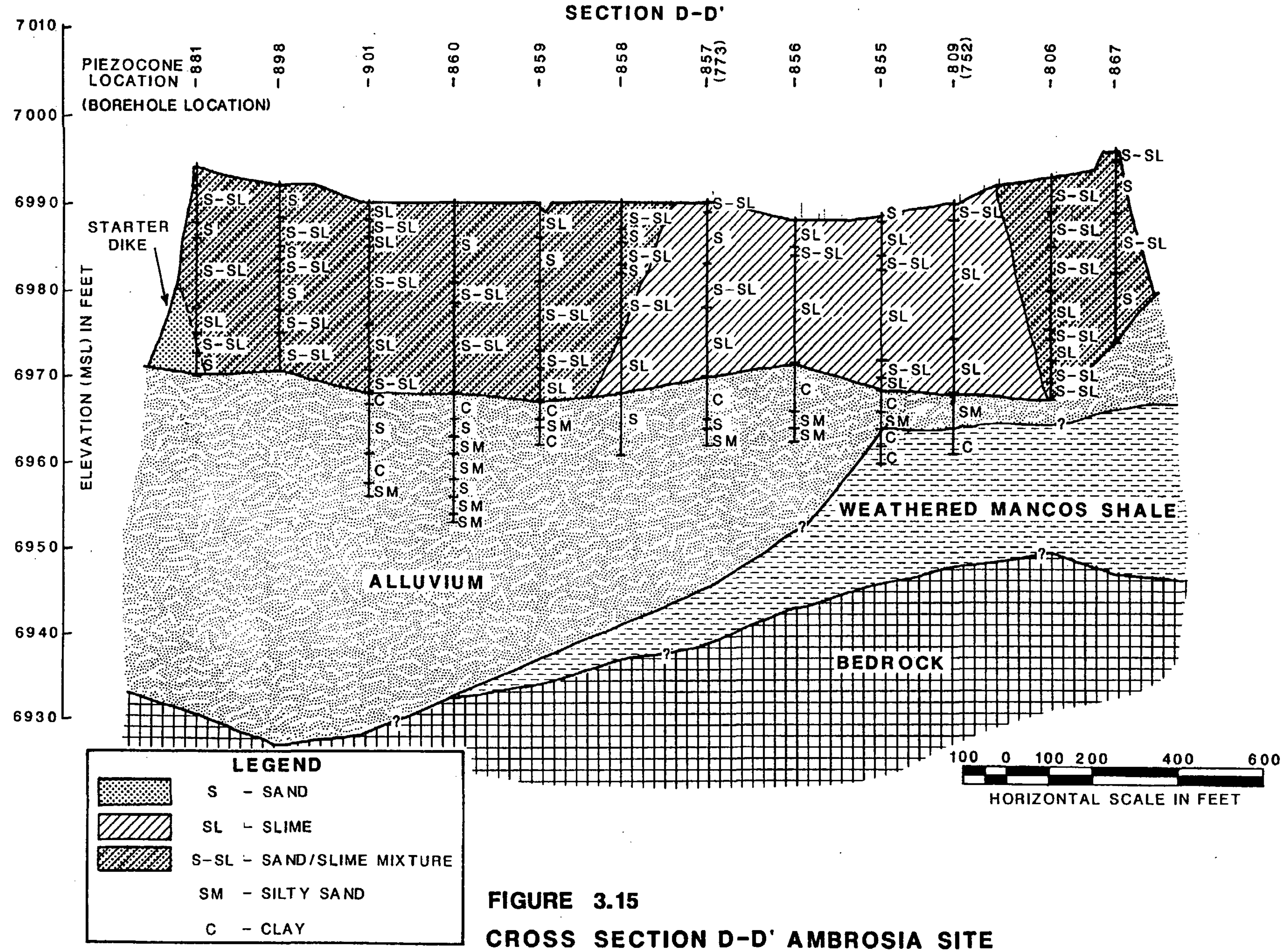


FIGURE 3.15

CROSS SECTION D-D' AMBROSIA SITE

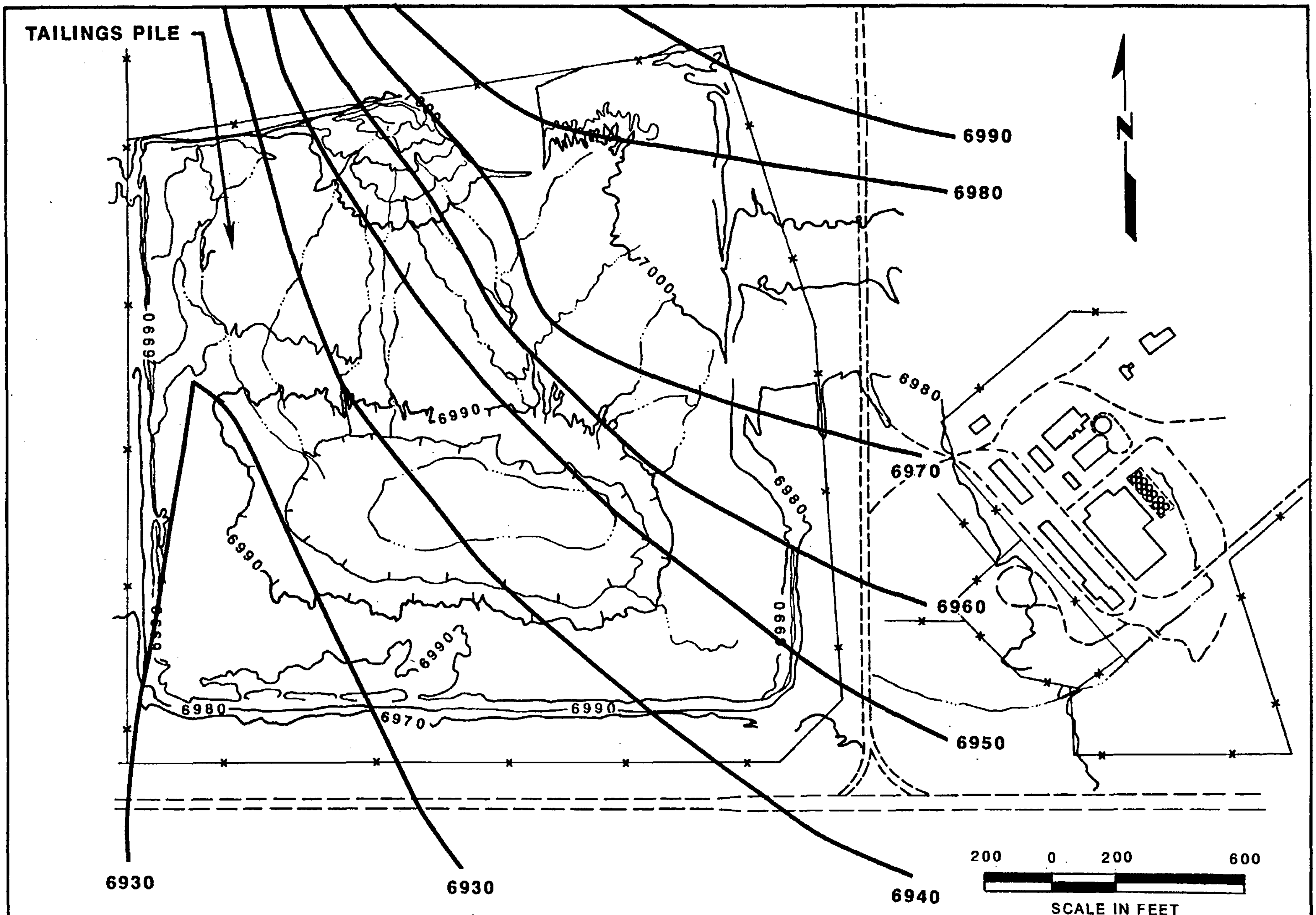


FIGURE 3.16 BEDROCK STRUCTURAL CONTOUR MAP

away. In any case, the tailings over the weathered Mancos appear to cause a perched water table in the area. This perched water table and engineering properties of the foundation soils are discussed in more detail in Appendix D, Site Characterization.

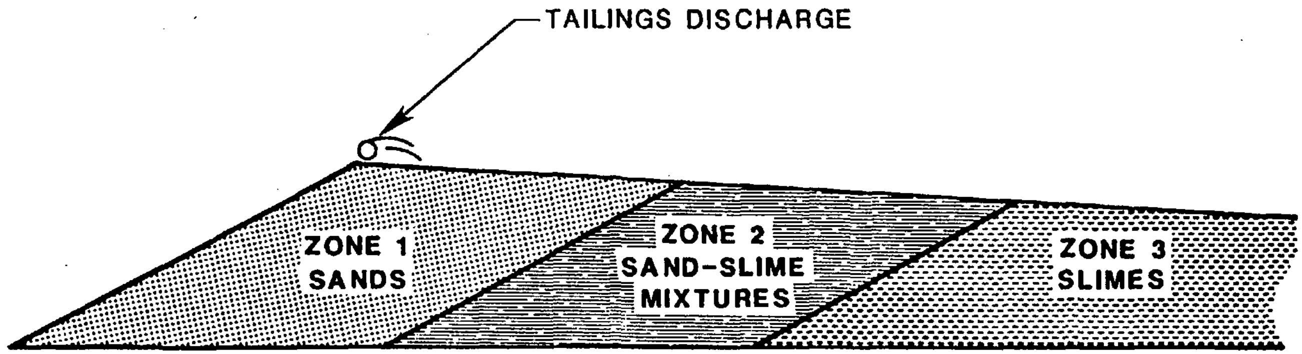
3.6.2 Tailings

Materials forming the tailings can generally be put into one of three categories: sand, sand-slime mixture, and slime. The limits for classifying these materials were set at zero to 30 percent passing the No. 200 sieve for the sand, 30 to 70 percent for the sandslime mixture, and 70 to 100 percent for the slime. Using these criteria, the laboratory tests were used to classify the tailings into one of the three categories. Carbonate leach tailings are generally finer than acid leach tailings and since the tailings at Ambrosia Lake were processed using the carbonate leach method, the tailings were predominantly sand-slime and slimes.

According to Purtymun et al. (1977), the tailings were pumped to the disposal area, which was originally surrounded on four sides by starter dikes. The tailings were discharged from pipes along the inner side of the dikes. As the impoundment filled, a second tier of dikes was constructed along the southern and western edges of the impoundment. Because the eastern edge is covered with wind-deposited tailings, it is not known if the second tier was constructed along this edge. The first tier was constructed of natural materials; however, the second tier appears to have been constructed of natural materials with some tailings.

The tailings impoundment at Ambrosia Lake was constructed using the upstream method, which involves discharging the tailings peripherally from the crest to form a beach. The upstream method of discharge encourages segregation of the grain sizes. The coarser particles occur near the outer portion of the embankment and the slimes are toward the center of the pond. Limits between the sands, sand-slime mixtures, and slimes are often difficult to locate because segregation during deposition is a gradual and continuous process. Figure 3.17 shows the conceptual material type variation for a tailings deposit constructed using the upstream method. A model developed by Kealy and Busch (1971) was used as a guide to plot the position of various types of tailings. The width of each zone depends on several different factors such as the initial proportion of sands and slime within the mill slurry, the location of the pond relative to the discharge, and whether the discharge is at a single point or distributed evenly across the embankment crest. Small slime stringers may be in the sands or vice versa; therefore, only generalizations can be made for the different zone widths.

Figure 3.18 shows a plan view of the tailings impoundment and the different material-type locations. This map was determined by plotting the different percentages of sand, sand-slime mixture, and slimes for each piezocone hole and then dividing the pile



REF: KEALY & BUSCH, 1971.

FIGURE 3.17
CONCEPTUAL MODEL OF MATERIAL VARIATION WITHIN A TAILINGS DEPOSIT

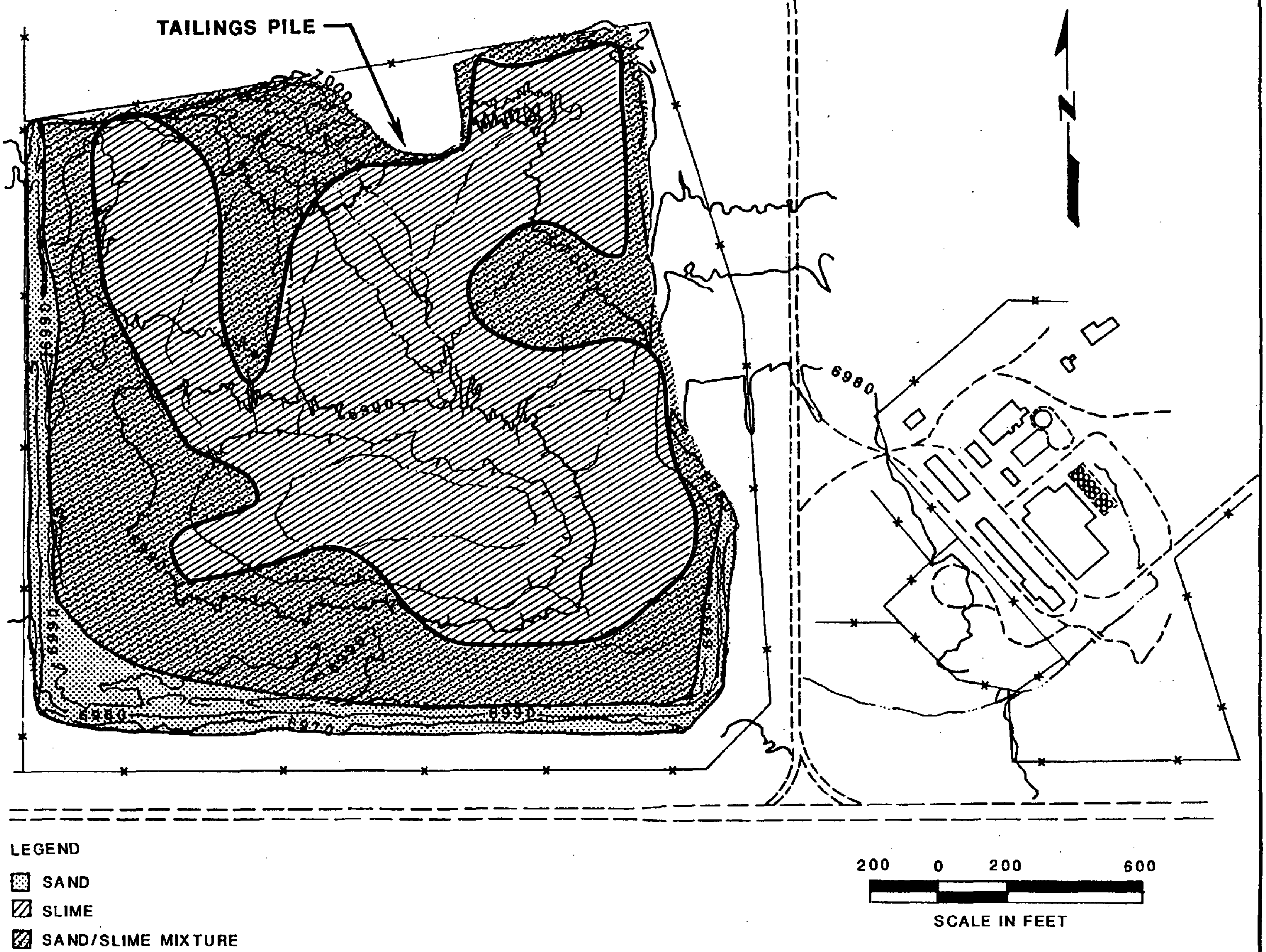


FIGURE 3.18 GENERAL MATERIAL TYPE LOCATIONS FOR AMBROSIA TAILINGS

according to the largest percentage of material recorded in each piezocone hole.

The starter dike location was determined by locating what is left of the downstream toe and then assuming an upstream slope of two horizontal to one vertical. It is not known if the starter dike was constructed with compacted engineered fill or by piling loose dirt to the desired height. Some compaction is believed to have been done; however, to be conservative in the design, it is assumed that the entire starter dike was constructed of loose material.

Discharge of the tailings slurry was done on nearly all sides of the embankment, as noted by the distribution pipes currently along the crests. It appears that the major tailings discharge was done on the northern-most edge of the pile since the tailings pile slopes to the south. Some of the tailings were discharged near the center of the impoundment, as evidenced by the present discharge pipes running from the embankment crest to the interior of the pile. Section D.7 of Appendix D, Site Characterization, discusses the engineering properties of the tailings materials.

In order to define the in situ consolidation and settlement behavior of the tailings, two trial embankments were constructed. The amount and the rate of settlement (hence consolidation) of the tailings were measured with numerous instruments at each trial embankment. A detailed description of the final embankment and the interpretation of the results are given in the calculations that accompany this report. Generally, the trial embankment showed that the rate of consolidation is greater and the amount of settlement is slightly less than predicted from laboratory tests.

3.6.3 Radon/infiltration barrier

Mancos Shale from an area one mile north of the Ambrosia Lake site will be used as a radon/infiltration barrier over the tailings. This area was chosen because the weathered Mancos Shale is near the surface and little overburden stripping would be required. The weathered Mancos Shale is a very clayey material that has been shown in laboratory tests to be efficient in controlling radon gas release. Engineering properties of the proposed radon/infiltration barrier materials are discussed in Section D.6 of Appendix D, Site Characterization.

3.6.4 Contaminated materials

Prior to placement of the radon/infiltration barrier, the pile will be covered with a layer of windblown tailings and contaminated alluvium from beneath the north part of the tailings pile. This layer will be predominately alluvium, which is composed of very silty to clayey sands. The compacted characteristics and engineering behavior of the alluvium are discussed in Appendix D, Site Characterization, Section D.5.

3.6.5 Erosion barrier

The rock proposed for erosion protection is hard, dense basalt boulders that will come from an existing quarry near the town of San Mateo, south of the processing site. The basalt will have to be drilled and blasted.

An outcrop of Dakota Sandstone 6.5 miles south of the Ambrosia Lake site and another basalt deposit were sampled and tested as part of an evaluation of alternate sources of rock for erosion protection. The sandstone rock did not meet the NRC durability requirements (NRC, 1985). Based on these findings, Dakota Sandstone in the area is not considered acceptable rock for erosion protection. The original basalt deposit was not selected because access would have required road construction though valuable big game habitat that was disfavored by the U.S. Forest Service. Section D.6 of Appendix D, Site Characterization, describes the rock durability test results.

3.7 GROUNDWATER

The Ambrosia Lake tailings pile is underlain by alluvium which grades into weathered Mancos Shale on the eastern side of the site. The alluvium and weathered Mancos Shale are hydraulically interconnected and behave as a single hydrologic unit. The Tres Hermanos-C sandstone of the lower Mancos Shale subcrops into the alluvium beneath the western side of the tailings site. Other hydrostratigraphic units beneath the site which may be water-bearing include (in descending order) the Tres Hermanos-B and -A sandstones of the lower Mancos Shale, the Dakota Formation, and the Westwater Canyon Member of the Morrison Formation.

The condition of saturation in the alluvium/weathered Mancos Shale at the site exists due to the uranium mining activities in the area. Seepage from an unlined mill make up process water pond, discharge of mine water from the Ann Lee Mine, and seepage from the tailings have artificially recharged groundwater in the alluvium and weathered Mancos Shale. Groundwater in the area of saturation in the alluvium/weathered Mancos Shale north of the pile flows to the southwest under the tailings along the southwesterly sloping contact of the Mancos Shale under a hydraulic gradient averaging 0.025 foot per foot. The average hydraulic conductivity in the alluvium/weathered Mancos Shale is 3.48×10^{-4} centimeter per second (cm/s) and the average linear groundwater velocity is 6.69×10^{-5} cm/s.

The alluvium/weathered Mancos Shale and the Tres Hermanos-C sandstone are incapable of producing more than 150 gallons per day, which classifies the groundwater contained in these units as limited use (Class III) groundwater. The existing level of saturation in the alluvium/weathered Mancos Shale will probably not be sustained after remedial actions are completed. Groundwater within the Tres Hermanos-C sandstone is recharged mostly from seepage from the alluvium in the subcrop area. The extent of recharge from the alluvium will diminish after remedial action.

The Tres Hermanos-C sandstone is only basically saturated, receiving most of its recharge from the overlying alluvium/weathered Mancos Shale where it subcrops on the western side of the pile. Groundwater within the Tres Hermanos-C sandstone flows to the northeast in the direction of regional dip under a hydraulic gradient averaging 0.025 ft/ft. The average hydraulic conductivity in the Tres Hermanos-C sandstone is 2.67×10^{-4} cm/s and the average linear groundwater velocity is 1.37×10^{-4} cm/s.

Groundwater within the Westwater Canyon Member of the Morrison Formation flows to the northeast in the direction of regional dip under a hydraulic gradient averaging 0.026 ft/ft. The average hydraulic conductivity in the Westwater Canyon Member is 4.31×10^{-4} cm/s and the average linear groundwater velocity is 1.14×10^{-4} cm/s.

Because there was originally no saturation in the alluvium, no pre-operational water quality data is available. It is only possible to establish existing water quality as background for the isolated pocket of saturation in the alluvium and weathered Mancos Shale.

Maximum observed concentrations of chromium, molybdenum, nitrate, lead, selenium, silver, uranium, and activities of radium 226 and 228 and gross alpha in pore fluids in the tailings and unsaturated alluvium beneath the tailings exceed the proposed MCLs.

Maximum observed concentrations of chromium, molybdenum, nitrate, lead, selenium, silver, uranium, and activities of radium 226 and 228 and gross alpha in groundwater in the alluvium/weathered Mancos Shale exceed the proposed MCLs. Maximum observed concentrations of cadmium, chromium, molybdenum, nitrate, selenium, silver, uranium, and activities of radium 226 and 228 and gross alpha in groundwater in the Tres Hermanos-C sandstone member exceed the proposed MCLs.

Maximum observed concentrations of cadmium, chromium, lead, molybdenum, selenium, silver, uranium, and activities of radium-226, radium-228, and gross alpha in groundwater in the Westwater Canyon Member of the Morrison Formation exceed the proposed MCLs.

Geochemical simulation of mixing tailings pore fluids with mill makeup water suggests that groundwater in the alluvium/weathered Mancos Shale is derived largely from these two sources. Concentrations of nitrate, a conservative species, are relatively the same in groundwater in the alluvium/weathered Mancos Shale and the Tres Hermanos -C sandstone suggesting much of the groundwater in the Tres Hermanos-C sandstone is derived from seepage from the alluvium/weathered Mancos Shale.

A comparison of concentrations of hazardous constituents in the Tres Hermanos-C sandstone with those in the Westwater Canyon member of the Morrison Formation indicates that seepage down mine shafts and ventholes will not influence water quality in the Westwater Canyon Member. Concentrations of most hazardous constituents in the Tres Hermanos-C sandstone are lower than those in the Westwater Canyon Member and the relative rate of groundwater underflow in the Westwater Canyon member compared to the Tres Hermanos-C sandstone assures that no water quality impacts will occur in the Westwater Canyon Member.

3.8 SURFACE WATER

There are no natural perennial streams at the Ambrosia Lake site. The Arroyo del Puerto, the principal drainage channel for the Ambrosia Lake area, is a tributary of San Mateo Creek. Flow in the channel has been sustained by mine water discharges, creating a perennial stream from the late 1950s until 1980. Flow within the Arroyo del Puerto has been a source of recharge to the alluvium along its course toward San Mateo Creek. This saturation in the alluvium does not extend as far as the Ambrosia Lake tailings pile, and alluvial wells south of the pile are dry. Saturation at the Ambrosia Lake processing site is localized and distinct from saturation along the Arroyo del Puerto. Water quality in the Arroyo del Puerto reflects the quality of mine water discharges and contains concentrations of gross alpha, Ra-226, molybdenum, selenium, uranium, and possibly chloride and/or sulfate that exceed background levels designated from upstream samples from San Mateo Creek (Gallaher and Goad, 1981).

Ponded water on the tailings pile resulted from rainfall and collected in the depression at the south central portion of the existing pile until it was drained into a lined wastewater retention basin in 1988. Additional ponds in the vicinity of the site, all of which are usually dry, include abandoned mine ponds, abandoned sewage ponds, and various stock watering ponds northeast of the mill. Surface water-quality analyses results are included in Appendix D, Site Characterization.

None of the surface water in intermittent drainages from San Mateo Mesa or within the Arroyo del Puerto are utilized as a potable water source. However, some surface water from the Arroyo del Puerto has been diverted for stock watering.

The watershed and associated drainage network above the site were evaluated to determine the impact that intense storms and flooding would have on the site. The watershed covers 3.8 square miles and is divided into two separate ephemeral drainage pathways, one north of the site and one northeast of the site. Flood analysis included a determination of the Probable Maximum Flood conditions. This is discussed in greater detail in the surface water hydrology portion of Appendix D, Site Characterization, and in calculations supporting Appendix F, Subcontract Documents.

SITE EROSION PROTECTION MEASURES
FROM SURFACE WATER FLOW IN THE ARROYO DEL PUERTO
AMBROSIA LAKE MILL
AMBROSIA LAKE, NEW MEXICO

Prepared for:
Rio Algom Mining LLC
P.O. Box 218
Grants, New Mexico 87020

October 2007

Prepared By:

TETRA TECH, INC.

GLOBAL BCG, LLC

SITE EROSION PROTECTION MEASURES FROM SURFACE WATER FLOW IN THE ARROYO DEL PUERTO

AMBROSIA LAKE MILL
AMBROSIA LAKE, NEW MEXICO

Prepared for:

Rio Algom Mining LLC
P.O. Box 218
Grants, New Mexico 87020

Prepared by:

TETRA TECH, INC.

GLOBAL BCG, LLC

Tetra Tech Inc.
6121 Indian School Road, NE
Suite 200
Albuquerque, New Mexico 87110

OCTOBER 2007

TABLE OF CONTENTS

1.0 INTRODUCTION

The following design report was prepared by Tetra Tech Inc. for Rio Algom Mining LLC (Rio Algom) to evaluate erosion protection measures to protect the site from the effects of surface water flow during storm events in the Arroyo del Puerto. Initially, an option was considered to return the Arroyo del Arroyo channel to its historic general natural course and prevent future lateral migration of the re-established channel towards Tailings Pond 3. However, this historic location placed it between Tailings Pond 3 on one side and Tailing Ponds 4, 5, & 6 on the opposite side. The resulting evaluation was required to consider the impact from a probable maximum flood (PMF) down the Arroyo del Puerto and the erosion protection necessary to protect the pond areas containing tailings or residual contaminants. Three options were evaluated with the preferred option primarily involving diversion of the Arroyo del Puerto to the east of Tailing Ponds 4, 5, & 6 *utilizing an embankment and a new excavated channel that would rejoin* the original arroyo near the northeast corner of Tailings Pond 9. Additionally, the historic location of the arroyo west of Tailing Ponds 4, 5, & 6 would be designed to provide drainage of onsite runoff. This report provides the basis for the design and construction of the new embankment and channel as well as the historic channel draining onsite drainage, together with drawings and specifications for construction. In addition, an evaluation of the geomorphic processes affecting the Arroyo del Puerto was performed to determine the long-term stability of the design with respect to aggradation or degradation processes.

1.1 Historical Perspective

The Arroyo del Puerto historically has been a relatively narrow channel, in a broad alluvial flood plain. Historically, it was a dry wash and flowed only in response to significant rainfall events and periods of prolonged snow melt. In the late fifties, several mining companies began sinking mining shafts, with subsequent pumping from the Westwater Formation into the Arroyo del Puerto. The flows in the Arroyo del Puerto reached San Mateo Creek about 4 miles to the south. These flows eventually decreased with cessation of mining in the valley. The Creek then became dry until it reached the United Nuclear-Homestake IX plant in Section 25, northwest of the mill where the Homestake IX discharges were added to the arroyo.

In late 1976, the arroyo was realigned by Kerr McGee as part of their operations to flow north and east of Tailings Pond Nos. 4, 5 and 6 away from Ponds 1 and 3 (Figure 1.1). This new diversion channel rejoined the original arroyo Tailing Ponds 4, 5, & 6 near the northeast corner of Tailings Pond 9. Drainage from the channel reach of the abandoned creek was captured behind a small dam and pumped back into Tailings Pond 3.

The initial Rio Algom reclamation plans considered restoration of the Arroyo del Puerto to its original channel as nearly as achievable to the pre-1976 grade and alignment. It was thought that the stream restoration would re-establish the general structure, function and self sustaining behavior of the arroyo to that which existed prior to the diversion channel construction.

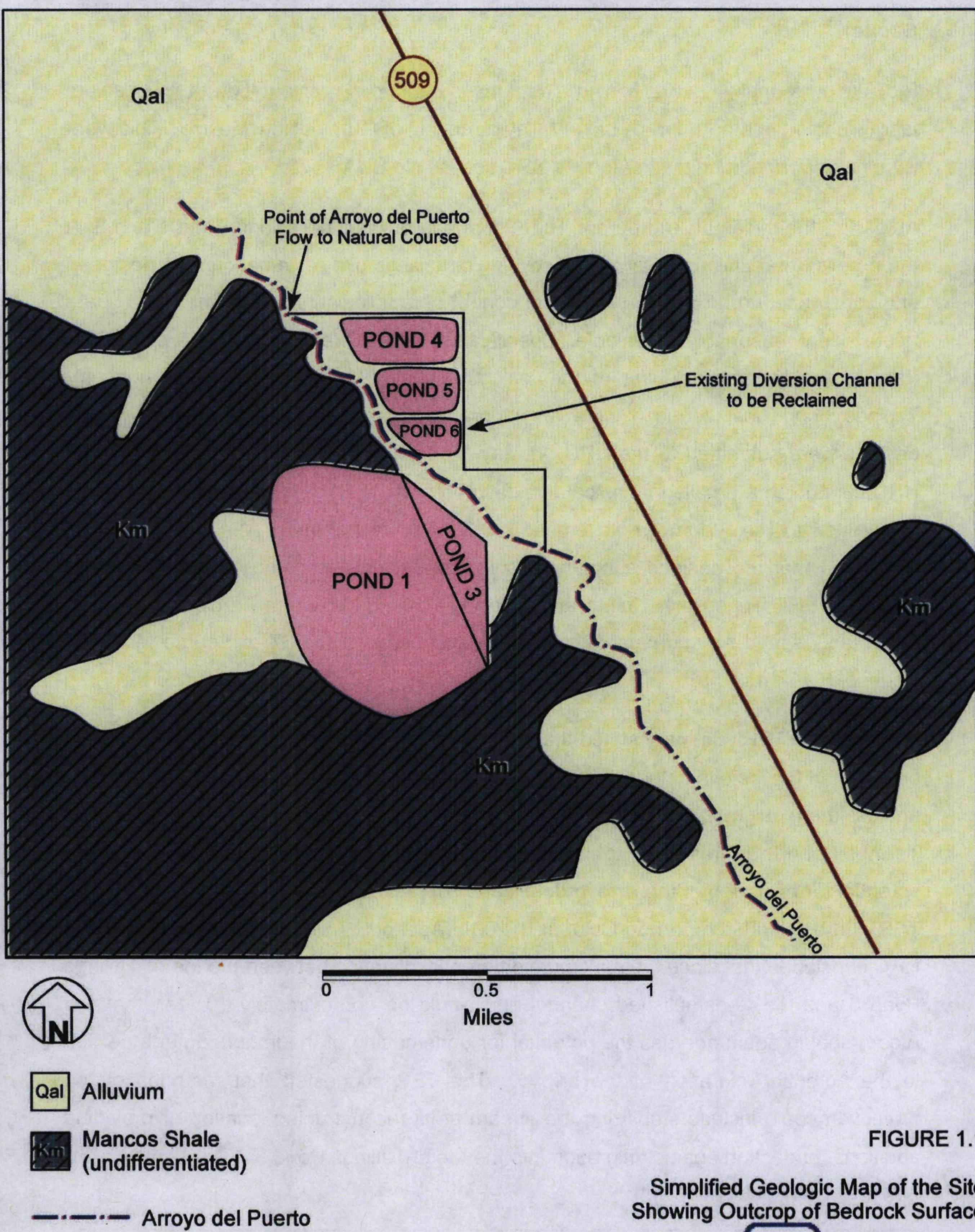


FIGURE 1.1

Simplified Geologic Map of the Site
Showing Outcrop of Bedrock Surface

TETRA TECH, INC.

Scope

Rio Algom, formally Quivira Mining Company is conducting reclamation of its Uranium facility located in the Ambrosia Lake Valley northeast of Grants, New Mexico. This work is being performed under Rio Algom's NRC license No SUA-1473.

As part of the reclamation program, Rio Algom has reclaimed Tailings Pond 1 and is in the process of reclaiming Tailings Pond 3. The tailings pile reclamation was designed and constructed to provide assurance of control of radiological hazards for 1,000 years to the extent reasonably achievable. Specifically, the plan meets Appendix A of 10 CFR Part 40 for decommissioning of the tailing ponds. Erosion protection designs for Tailings Pond Nos. 1 and 3 were an integral part of the reclamation plan. These designs were submitted to the NRC on May 16, 2005 and September 26, 2002. The NRC conducted a detailed technical evaluation report (TER), on the design, which was transmitted to Rio Algom on November 27, 2002 (See Appendix A). The NRC staff concluded that the designs submitted appropriately addressed the long-term erosion protection of Tailings Pond Nos. 1 and 3, for a Probable Maximum Precipitation (PMP) event, and issued Amendment 51 to update License condition 37 of Source Materials License, SUA-1473.

However, the TER summary stated that the toe of Tailings Pond 3 (at Section 3) should be revisited (i.e. re-evaluated) to determine if the erosion protection adequately protects against lateral migration of the Arroyo del Puerto, thus potentially undercutting the toe of Tailings Pond 3. In response to this TER, Rio Algom submitted a report assessing the potential for migration of the Arroyo del Puerto (Appendix B). The NRC issued another TER addressing this report on October 5, 2004 (Appendix A). This second TER by the NRC concluded that since the maximum differential distance between the toe of Tailings Pond 3 and the re-established channel bed would be approximately 10 feet, that Rio Algom should again address the potential for undercutting of the impoundment toe due to the potential migration of the arroyo. The TER suggested that methods of toe protection could include stabilizing the stream at its reconstructed location or providing additional protection against migration into the toe of Tailings Pond 3.

Subsequent to the second TER, NRC also expressed concern for remaining subsurface contaminants beneath the previous locations of Tailings Ponds 4, 5, & 6. NRC indicated that in addition to Tailings Pond 3, these materials needed to be protected from dispersal by the impact of a PMF down the Arroyo del Puerto.

Rio Algom has evaluated three options for cost impacts based on these design considerations. These options are described as follows:

- Option 1: Re-align the Arroyo del Puerto to the historic alignment and design for PMF streamflows. Protect Tailings Ponds 4, 5, & 6 and the channel for the resulting PMF flow velocities and scour depths, as well as the toe and sideslope of Tailings Pond 3.
- Option 2: Re-align the Arroyo del Puerto to the historic alignment to provide interior site drainage and protect Tailings Ponds 3, 4, 5, & 6 and the channel for the runoff from a Probable Maximum Precipitation (PMP). Divert upstream PMF drainage in the Arroyo del Puerto to the east of Tailing Ponds 4, 5, & 6 utilizing an embankment and a new excavated channel that would rejoin the original arroyo near the northeast corner of Tailings Pond 9.
- Option 3: Re-align the Arroyo del Puerto to the historic alignment and design for PMF stream flows. Build a weir embankment at the downstream end of Tailings Pond 6 to back up flood flows and reduce flow velocities over Tailings Ponds 4, 5, & 6. Protect Tailings Ponds 3, 4, 5, & 6 and the channel for the resulting PMF flow velocities and scour depths.

The evaluation determined that Option 2 would be more cost effective and would provide better protection of the area of Tailings Ponds 4, 5, & 6 as well as mitigate the concern for lateral migration into Tailings Pond 3. The following design summary and associated drawings addresses the NRC's concerns and presents erosion protection measures for the interior site drainage as well as the PMF design for the diversion embankment/channel as shown on Sheet 1.

The interior site drainage and erosion protection is discussed in Section 2 and the applicable calculations are contained in Appendix C. The Diversion

Embankment/Channel PMF analysis and erosion protection is discussed in Section 3 and the applicable calculations are contained in Appendix D. Section 4 discusses erosion protection specifications to include requirements for rock gradations, rock filters, rock quality, rock placement, and a summary of estimated volumes required. Section 5 contains a geomorphic evaluation summary that is supported by calculations and a geomorphic report contained in Appendix E. Section 6 contains a design summary, Section 7 contains references, and Section 8 contains the design drawings (Sheets 1 thru 23). In order to better show some of the erosion protection details on Sheet 4, a map size version of this drawing has been placed into a map inset at the back of the report.

ENVIRONMENTAL ASSESSMENT FOR THE SOIL DECOMMISSIONING PLAN RIO ALGOM MINING LLC'S URANIUM MILL FACILITY, AMBROSIA LAKE, NEW MEXICO

Final Report

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Waste Management and Environmental Protection

License SUA-1473

DOCKET 40-8905

TAC-LU0078

MAY 15, 2006

Table of Contents

1.0 INTRODUCTION

By letter dated January 19, 2005, Rio Algom Mining Limited Liability Corporation (Rio Algom) sent to the U.S. Nuclear Regulatory Commission (NRC), a *Soil Decommissioning Plan* for its Ambrosia Lake uranium mill tailings facility. In a followup to the proposed plan, Rio Algom submitted, under letters dated June 15, July 15, and September 27, 2005, a response to a request for additional information and a revised plan.

The plan addresses the methods and procedures to be implemented to ensure that soil remediation is performed in a manner that is protective of human health and the environment. The Uranium Mill Tailings Radiation Control Act, as amended, and regulations in Title 10 of the Code of Federal Regulations, 10 CFR Part 40 require that material at uranium mill tailings sites be disposed of in a manner that protects human health and the environment.

The Ambrosia Lake site is in the Ambrosia Lake mining district of New Mexico, 25 miles north of Grants, New Mexico. It began processing ore in 1958 and processed approximately 33 million tons of ore through 1985. The facility continued to be an active uranium production facility through December 2002. Reclamation of the tailings management facilities commenced in 1989 with the initiation of consolidating the top surface of the largest tailings impoundment. Reclamation activities have at times included excavation and disposal of unlined evaporation pond residues, contaminated soil cleanup, reclamation of the tailings impoundments, construction of surface water erosion protection features, and demolition of the mill buildings.

The original tailings disposal area was constructed in 1958 and originally consisted of eight ponding areas. Tailings Impoundments ponds 1 and 2 were used for solids disposal, pond 3 was a decant and seepage collection pond, and ponds 4 through 8 were used for evaporation of liquids decanted from ponds 1 and 2. Ponds 4 through 8 were unlined. Starter dike and retention dikes were constructed from clayey natural soils that were present on the site. Tailing disposal operations utilized the upstream spigoting method. By the end of 1984, nearly 33 million tons of tailing solids had been deposited at the site and no failures allowing discharge of radioactive material outside the restricted area are known to have occurred.

All unlined evaporation ponds (pond 4 through 8) were taken out of service in 1984. Following solution transfer from these unlined ponds to lined evaporation cells, consolidation and removal of accumulated pond sediments in ponds 4-8 were transported to pond 2 for final disposal.

Lined ponds 9 and 10 were constructed in 1976, and were also used for evaporation of liquids decanted from ponds 1 and 2. Pond 10 was removed from service in 1984 and allowed to dry out. The accumulated sediments, liner material, and contaminated soils beneath the liner from pond 10 were relocated to pond 2. The area was cleaned down to bedrock (shale and sandstone), and then backfilled with 0.91 meter (3 feet) of fill material. Pond 9, which remains in service to facilitate on-going evaporation needs, is scheduled to be reclaimed in the latter part of 2006 or early 2007.

Ponds 11 through 15 were constructed in 1976, and ponds 16 through 21 were constructed in 1979. These synthetically lined ponds are referred to as the "Section 4 ponds." They are located along the southeastern portion of the site and were used to evaporate liquid wastes generated from Rio Algom's uranium ore processing mill. These ponds have an overall evaporative area of 256 acres with a total holding capacity of 1570 acre-feet. Additional wastewater streams evaporated at the Section 4 ponds included wastewater from the ion exchange plant consisting of backwash solutions and resin regeneration solutions. Groundwater collected as part of the alluvial and bedrock groundwater remediation plan, and other mill process solutions, were also disposed via evaporation at the Section 4 ponds. The ponds remained in active service through April 2005. Closure of all lined ponds will be performed pursuant to the Lined Pond Relocation Plan approved by NRC in June 2005.

The applicant stated that this *Soil Decommissioning Plan* is one component of the overall site decommissioning plan. The licensee has previously addressed and NRC has approved the remaining site-wide decommissioning plan elements through separate licensing actions including closure of tailings pond 1 and 2, mill demolition, relocation of lined evaporation pond sediments, and groundwater remediation.

The plan addresses the soil decommissioning of the entire site associated with the facility license. The plan also addresses areas of deeper soil contamination, including ponds 4 through 8, and pond 10. The applicant is requesting to close these areas through the application of alternate release criteria (ARC) by comparison of the site-specific dose assessment with the "benchmark dose." Construction methods used for the unlined ponds resulted in creating contaminated soils at depths beneath and in the vicinity of the unlined ponds that can exceed twelve feet from current surface elevation. Site conditions make excavation of these soils that are impacted at depth technologically and economically infeasible to remediate and create unnecessary safety and health concerns to employees.

Some other onsite areas of possible deeper soil contamination lack adequate characterization data as a result of on-going licensed activities. These areas include the mill area and the lined evaporation ponds (pond 9 and "Section 4 ponds"). Other areas addressed in this plan are the saturated area immediately north of the treatment pond which resulted from mine water seepage, the former saturated zones adjacent to pond 9 which existed prior to the installation and operation of the dewatering trench, and pipelines that contained process solutions.

2.0 NEED FOR THE PROPOSED ACTION

A *Soil Decommissioning Plan* is required by 10 CFR Part 40. The purpose of the plan is to remediate the windblown tailings, effluent contaminated soils, and soil contamination originating from the milling operation and disposal area and to demonstrate that the cleanup plan was successful in remediating the contaminated soils to comply with the proposed release criteria. For areas of deeper contamination attributed to licensed activities, Rio Algom will utilize ARC to allow these soils to be left in place protected by an engineered (erosion protection) barrier.

3.0 THE PROPOSED ACTION

The proposed action is modification to a license condition of Source Material License SUA-1473, to approve Rio Algom's *Soil Decommissioning Plan* to remediate soil impacts attributable to licensed activities. Following approval of the *Soil Decommissioning Plan*, Rio Algom will develop and implement operational procedures to verify that the area meets the approved cleanup criteria. Following approval by NRC of successful remediation of the area pursuant to the *Soil Decommissioning Plan,* the area will be stabilized and the site will eventually be transferred to the US Department of Energy.

4.0 ALTERNATIVES TO THE PROPOSED PLAN

The alternative to in-place stabilization is the no-action alternative. The no-action alternative would not provide an adequate long-term solution for the uranium byproduct material. However, it would require active maintenance for the life of the waste site.

In-place stabilization will provide a reasonable assurance of containing the radiological hazards for 1000 years. Further, to the extent practical in-place stabilization will limit the release of radon-222 from uranium byproduct materials and radon-220 from thorium by-product materials to the atmosphere so as not to exceed an average of $20pCi/m^2/sec$, and the direct gamma exposure from the reclaimed tailings cells will be reduced to background levels.

5.0 DESCRIPTION OF AFFECTED ENVIRONMENT

5.1 Land Use

The site is located approximately 24 miles due north of Grants, New Mexico, in the Ambrosia Lake valley. Uranium mining started in this area in mid-1950s, and 17 mines are located within approximately 3 miles of the site (Rio Algom, 2005a). Land uses within 2 miles of the site are grazing, utilities, and mine reclamation activities, according to the 2005 land use survey (Rio Algom, 2005b).

5.2 Geology

5.2.1 Regional Geology

Rio Algom's mill and tailings facility is located north of the Zuni Uplift portion of the San Juan Basin. The basin is characterized by broad areas of relatively flat-lying sedimentary rocks, dipping to the northeast; portions of the basin are covered with alluvium and basalt flows. The site is within the Ambrosia Lake valley, which is formed by the Mesa Montanosa to the west and the San Mateo Mesa to the east. The stratigraphic sequence of hydrologic significance at the site consists of, in descending order, the Arroyo del Puerto alluvium (alluvial aquifer), the Mancos Formation and Tres Hermanos A and B (TRA and TRB) sandstones, the Dakota Sandstone, the Brushy Basin and the Westwater Canyon members of the Morrison Formation. The ore-bearing unit in the vicinity is the Westwater Canyon. Bedrock formations above the Westwater Canyon Member of the Morrison Formation have essentially been dewatered by ventilation holes and mine shafts located to the north and east of Rio Algom's mill and tailings facility. Units that have been affected by milling activities are the alluvium, the TRB sandstone, and the Dakota Sandstone.

5.2.2 Site Geology

The mill site and Tailings Impoundments 1 and 2 are located on the weathered Mancos Formation (saprolite) or on alluvium overlying the Mancos section. The alluvium consists of clay and clayey sand derived from reworked shales of the Mancos Formation. Bedrock units impacted by tailings seepage are the Dakota Sandstone that underlies ponds 7 and 8, and the TRB that underlies the saprolite throughout most of Tailings Impoundments 1 and 2. Most of the seepage from Tailings Impoundments 1 and 2 migrates laterally through the alluvium and shallow saprolite in the direction of the surface slope to the alluvial aquifer, where it enters the interception trench. Seepage that enters the unweathered bedrock beneath Tailings Impoundments 1 and 2 slowly migrates through the TRB to the north and northeast of the Facility in the general direction of the dip. The dewatering trench located between pond 7 and pond 2 has minimized any tailings seepage to the TRA that underlies the saprolite and alluvium in the general vicinity of pond 7.

5.3 Water Resources

5.3.1 Surface Water

Prior to mining activity, the Arroyo del Puerto was an ephemeral drainage as flow in the arroyo occurred only in response to large rainfall or snowmelt events. When mine dewatering was occurring, the arroyo was dry until it reached the discharge point for treated mine water. Mine discharges are permitted under a National Pollutant Discharge Elimination System (NPDES) permit issued by the Environmental Protection Agency. As an example, during 1999 an average of 337,000 ft^3/d of treated mine water was discharged to the Arroyo del Puerto channel. Some water was then diverted from the creek for mine injection. Since January 2000, when mine injection ceased, an average of 125,000 ft^3/d of treated mine water has been released to the Arroyo del Puerto channel. Water flowing in the arroyo infiltrates into the alluvium to facilitate the groundwater corrective action plan implemented at the site for the alluvial unit Other than minimal precipitation recharge, this infiltration is the only source of recharge to the alluvial groundwater system. As of December 2005, no water has been discharged into the Arroyo del Puerto

5.3.2 Groundwater

5.3.2.1 Bedrock Aquifers

The principal near-surface bedrock hydrogeologic units beneath the site are the TRA, the TRB, and the Dakota Sandstone. The Mancos Formation serves as an aquitard that separates each of these water-bearing units. Groundwater flow within bedrock units is generally down-dip, toward the north-northeast. An exception is a small portion of TRB in the southeast portion of the study area. Interception trenches IT-2 and IT-3 intercept water flowing in the TRB to the east from beneath Tailings Impoundment 1.

A regional cone of depression has formed within bedrock units beneath the site as a result from the dewatering of mines through vent holes and mine shafts. Bedrock units are recharged where they crop out or where they are covered by alluvium. Transmissivity values for TRB and Dakota of 4.7 square feet per day (ft^2/d) and 13 ft^2/d, respectively (Rio Algom, 2000b).

5.3.2.2 Alluvial Aquifers

Prior to mining in the area, natural sources of recharge to the alluvial system were insufficient to establish saturated conditions within the alluvium. Therefore, natural sources of recharge such as infiltrating overland flow and drainage are insignificant. Two principal sources of recharge to the system are currently maintaining the localized saturated condition: 1; infiltration of water from the Arroyo del Puerto bypass channel and 2; leakage from Tailings Impoundment 1

Current groundwater flow in the alluvial system is generally to the southeast with a gradient of approximately 0.006. A groundwater mound has formed in the northern portion of the study area, caused by infiltration from the Arroyo del Puerto bypass channel. North of this mound, groundwater flows north toward mine shafts and vent holes located in Section 30. South of the mound groundwater flows toward the northern half of trench IT-l, creating the groundwater sweep. Groundwater seeping from Tailings Impoundment 1 flows east toward trench IT-1.

Groundwater exits the alluvial system at the northern and eastern margins of the study area where vent holes and mine shafts intersect the water table. Alluvial groundwater also exits the southern end of study area as underflow beneath the Arroyo del Puerto through a narrow gap in the bedrock. Hydraulic gradients between the alluvial system and subcropping Tres Hermanos units are generally downward, indicating that some groundwater is probably moving from the alluvial system into subjacent sandstone units.

5.3.3 Background water Quality

Background values for the site were determined by the calculation of an upper tolerance limit (UTL) for constituent data sets that were either normally or lognormally distributed. In data sets that were not normally or lognormally distributed, the highest observed value was assigned as the UTL.

Rio Algom discussed the computation of background water-quality data because sources unrelated to site activities have impacted offsite water quality. Such sources include seepage from the nearby DOE UMTRCA Title I facility, mine pumping and discharge, and the runoff and erosion from mine spoils and ore piles. As a result, widespread ambient groundwater contamination has occurred that is unrelated to but inseparable from impacts related to milling at the site. Consequently, calculated background values may not be representative of groundwater in other parts of the Ambrosia Lake valley outside of mined areas.

Background Groundwater Concentrations

Table 1

Parameter	Background Concentration (UTL)
Gross Alpha (pCi/l)	16,726
Lead-210 (pCi/l)	36
Molybdenum (mg/l)	83
Nickel (mg/l)	0.14
Radium-226 & -228 (pCi/l)	196.1
Selenium (mg/l)	3.1
Thorium-230 (pCi/l)	5
Uranium (natural) (mg/l)	11.1

Source: Rio Algom, 2001

5.3.4 Current and Future Water Uses

Groundwater in the Ambrosia Lake area is used for irrigation and livestock watering. There are no irrigation or livestock watering wells in the alluvial aquifer in the vicinity of the tailings impoundments. The alluvial aquifer is not saturated anywhere except near the site and the DOE tailings impoundment and cannot provide sufficient water for use. Therefore, DOE obtained groundwater corrective action compliance and license termination at its facility through the application of supplemental standards. Rio Algom obtained alternate concentration limits ("ACL") for the site within the bedrock and alluvial units in February 2006. The land area where these ACL apply will be transferred to the DOE for long term stewardship upon license termination, thereby protecting the public and environment.

A list provided by the U.S. Geological Survey shows approximately 65 groundwater wells within a 25-mile radius of the facility. The closest groundwater supply well is completed in the Westwater Canyon Sandstone member of the Morrison Formation approximately 1.5 miles west of the site. A large reduction in water use and groundwater withdrawals has occurred in the Ambrosia Lake area over the past 10 to 15 years as a result of the decline of the uranium industry because of poor economic conditions. The current economic base in the Ambrosia Lake area is reclamation at the site and ranching. However, with the economics of uranium recovery in flux, it is possible that a future licensing action will require an environmental assessment to re-consider groundwater use.

5.4 Ecology (Flora and Fauna)

The site is located in McKinley County, New Mexico, where the U.S. Fish and Wildlife Service (FWS) has listed the following as threatened or endangered species that may be located in this county: A total of 118 species and subspecies are on the 2004 list of threatened and endangered New Mexico wildlife. However, only the Zuni Bluehead Sucker, Bald Eagle, Mexican Spotted Owl, Southwestern Willow Flycatcher, Interior Least Tern, American Peregrine Falcon, Arctic Peregrine Falcon, gray vireo was specifically identified as being either endangered or threatened in McKinley County.

By letter dated September 20, 2004, the U.S. Fish and Wildlife Service (FWS) transmitted the Federal list of threatened and endangered species for McKinley County, New Mexico, to NRC staff (FWS, 2004). According to this list, the following threatened and endangered species are found in McKinley County: bald eagle (*Haliaeetus leucocephalus*), black-footed ferret (*Mustela nigripes*), Mexican spotted owl (*Strix occidentalis lucida*) with critical habitat, southwestern willow flycatcher (*Empidonax traillii extimus*), and the Zuni fleabane (*Erigeron rhizomatus*). No habitat for these species has been identified at the site.

5.5 Meteorology, Climatology, and Air Quality

New Mexico has a mild, arid or semiarid, continental climate characterized by light precipitation totals, abundant sunshine, low relative humidity, and a relatively large annual and diurnal temperature range. Table 3 presents monthly average data from the Grants Airport except for pan evaporation data, which is from the Gallup ranger station.

Table 2

Climatic Data

Month	Avg. Temp (°F)	Avg Max. Temp. (°F)	Avg. Min. Temp. (°F)	Precip. (in)	Snowfall (in)	Wind Speed (mph)	Prevailing Direction	Pan Evaporation (in)
Jan	30.2	46.2	14.3	0.50	2.5	7.7	NW	0
Feb	34.9	51.3	18.5	0.42	22	9.2	NW	0
Mar	41.1	58.2	23.9	0.53	1.6	9.8	NW	0
Apr	48.8	67.4	30.1	0.47	0.3	11	W	6.61
May	57.5	76.3	38.8	0.54	0	10.3	W	9.31
Jun	66.9	86.3	47.5	0.57	0	9.9	W	12.12
Jul	71.6	88.2	55.0	1.71	0	8.0	SE	10.50
Aug	69.0	85.1	53.0	1.99	0	7.3	SE	8.70
Sep	62.2	79.7	44.6	1.32	0	7.8	NW	7.95
Oct	51.0	69.4	32.7	1.10	0.4	8.6	NW	5.07
Nov	39.1	56.1	22.1	0.59	0.9	7.7	NW	2.20
Dec	30.8	47.2	14.5	0.63	4.0	7.5	NW	0
Avg/ Total	50.3	67.6	32.9	10.37	11.9	8.7	NW	62.46

Source: Western Regional Climatic Center, 2005

5.6 Socioeconomic

According to the 2000 Census data, the closest population center to the site is Milan, which is 20 miles south of the site and immediately north of Grants (24 miles south of the site). As of the 2000 Census, Milan had a total population of 1,891 people (down from 1,911 people in 1990) with a median age of 29.8 years. Approximately 22 percent of the population is under 18 years old. Approximately 59 percent of the population 16 years old or older is in the workforce, and the median household income is $24,635. Approximately 29 percent of the population is below the poverty level.

As of the 2000 Census, Grants had a total population of 8,806 people (up from 8,626 people in 1990) with a median age of 34.4 years. Approximately 17 percent of the population is under 18 years old. Approximately 58 percent of the population 16 year old or older is in the workforce, and the median household income is $30,652. Approximately 22 percent of the population is below the poverty level (Census Bureau, 2005).

5.7 Historical and Cultural Resources

Implementation of the Soil Decommissioning Plan may have an effect on two identified archaeological sites resulting from ground disturbing activities that will occur at both archaeological sites. Rio Algom has submitted a Data Recovery Plan to the New Mexico State Historic Preservation Office ("SHPO") that addresses how the identified archaeological sites will be managed as part of the Soil Plan. The Data Recovery plan consists of ten elements: (1) research context; (2) resource description/current knowledge of the sites; (3) specific research questions; (4) specific procedures to excavate the sites; (5) procedures to implement the plan; (6) backfill; (7) analytical procedures; (8) schedule; (9) personnel; and (10) curation.

Archaeological activities will be in consultation with SHPO and will be conducted by qualified cultural resource specialists.

5.8 Public and Occupational Health

The site Health, Safety and Environment Management System provides adequate assurances to protect employees, the public and the environment. Health and safety programs implemented at the site address all facets of occupation safety including health physics monitoring. These comprehensive programs have continually demonstrated that employee exposures have been maintained as low as reasonably achievable.

The project has been designed to maximize protection of the public. Interaction with traffic from the general public is minimized through the construction of an overpass across the public highway. Fugitive dust from heavy equipment operation will be mitigated through the use of dust suppression methods on haul roads. The area will eventually be revegetated following work activities.

The NRC license requires the site to maintain comprehensive environmental monitoring programs that encompass, air, soil, sediment, surface water, groundwater, vegetation, radon, and direct gamma radiation. The facility air monitoring network was expanded as two additional ambient air monitoring stations have been installed to collect data to demonstrate that control measures are implemented and effective.

NRC staff is requiring quarterly monitoring of groundwater for the first 2 years followed by semiannual monitoring until license termination. Specifics of the Groundwater Monitoring Network are presented in detail within the Environmental Assessment for the Alternative Concentration Limits that was published Feb 24, 2006 (ML060380387).

The purpose of this monitoring is to ensure that Rio Algom remains in compliance with the groundwater standards in the license. Sampling data also allows monitoring of groundwater plume movement over time and distance, and assures that groundwater contamination will not present an unacceptable risk to human health or the environment in the future. If future data suggests that pollutant concentrations in groundwater exceed acceptable levels, Rio Algom will be required to take action.

DOE will propose a groundwater monitoring plan as part of the long-term surveillance plan to be approved by the NRC. As custodian of the tailings after termination of the site's license, DOE will be responsible for continued monitoring and any needed corrective action under an NRC general license.

5.9 Transportation

This action will result in increased traffic to and from the project site. However, increased traffic levels resulting from site employees will be below the traffic levels observed during the full operation of the facility. Dedicated haul roads to maintain segregation of traffic minimize the potential for traffic accidents occurring among project personnel. Interaction with traffic from the general public is minimized through the construction of an overpass across the public highway.

6.0 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

The NRC staff has reviewed the Rio Algom *Soil Decommissioning Plan* for its Ambrosia Lake uranium mill tailings facility. Based on its review, the staff has determined that the affected environment and the environmental impacts associated with the *Soil Decommissioning Plan* for the Ambrosia lake facility are bounded by the impacts evaluated in the"Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for License Termination of NRC-Licensed Nuclear Facilities" (NUREG-1496).

Since ceasing operations, the Ambrosia Lake site has utilize in-place stabilization to prevent contamination from spreading beyond its current locations. Access to the contaminated areas is controlled to assure the health and safety of workers and the public. No ongoing licensed activities are occurring in the facilities at this time. Contamination controls will be implemented during decommissioning to prevent airborne and surface contamination from escaping the remediation work areas, and therefore no release of airborne contamination is anticipated. However, the potential will exist for generating airborne radioactive material during decontamination, removal and handling of contaminated materials. If produced, any effluent from the proposed decommissioning activities will be limited in accordance with NRC requirements in 10 CFR Part 20 or contained onsite or treated to reduce contamination to acceptable levels before release, and shall be maintained ALARA. Release of contaminated liquid effluents are not expected to occur during the work.

Rio Algom and subcontractors will perform the remediation under the Ambrosia Lake license, with Rio Algom overseeing the activities and maintaining primary responsibility. The Ambrosia Lake facility has adequate radiation protection procedures and capabilities, and will implement an acceptable program to keep exposure to radioactive materials ALARA. As noted above, Rio Algom has prepared a decommissioning plan describing the work to be performed, and work activities are not anticipated to result in a dose to workers or the public in excess of the 10 CFR Part 20 limits.

Past experiences with decommissioning activities at E-12 sites similar to the Ambrosia Lake facility indicate that public and worker exposure will be far below the limits found in 10 CFR Part 20.

6.1 Environmental Impacts of the Alternatives to the Proposed Action

The alternative to in-place stabilization is the no-action alternative. The no-action alternative would not provide an adequate long-term solution for the uranium byproduct material. However, it would require active maintenance for the life of the waste site.

In-place stabilization will provide a reasonable assurance of containing the radiological hazards for 1000 years. Further, to the extent practical in-place stabilization will limit the release of radon-222 from uranium byproduct materials and radon-220 from thorium by-product materials to the atmosphere so as not to exceed an average of 20pCi/m^2/sec, and the direct gamma exposure from the reclaimed tailings cells will be reduced to background levels.

7.0 CONSULTATION WITH AFFECTED FEDERAL AND STATE AGENCIES

As required by NRC guidance, the FWS and the State of New Mexico were asked to provide input regarding the impacts of this action. The New Mexico Historic Preservation Division (NMHPD) was also contacted. In addition, the New Mexico Historic Preservation Division Web site was reviewed to identify any potential sites in the Ambrosia Lake area. No such historic sites were noted (NMHPD, 2005), however the licensee submitted to NMHPD a Data Recovery Plan (ML060670532) which identified several potential sites and provided a plan to address those sites as the remediation of site continues.

8.0 CONCLUSION

The NRC staff has reviewed the Soil Decommissioning Plan, as amended, and examined the impacts of the request. The potential impacts of the proposed action are limited to the land surface and are temporary due to construction activities.

The direct impacts to the surface will primarily be dust generation due to the removal and hauling of the material to the disposal area. Fugitive dust from heavy equipment operation will be mitigated through the use of dust suppression methods on haul roads. The site Health, Safety and Environment Management System provides adequate assurances to control impacts to the environment. Additional ambient air monitoring stations have been installed to collect data to demonstrate that control measures are implemented and effective.

The NRC staff is considering a request to approve the Soil Decommissioning Plan The alternatives available to the NRC are to:

1. approve the license amendment request as submitted; or

2. amend the license with such additional conditions as are considered necessary or appropriate to protect public health and safety and the environment; or

3. deny the request.

Based on its review, the NRC staff has concluded that the environmental impacts of the proposed action are not significant and, therefore, do not warrant denial of the license amendment request. Additionally, in the technical evaluation report (TER) being prepared for this action, the staff documents its review of the licensee's proposed action with respect to the criteria for soil remediation, specified in 10 CFR Part 40, Appendix A, and has no basis for denial of the proposed action.

The NRC staff have prepared this EA in support of the proposed action to amend the Rio Algom Ambrosia Lake License to approve the Soil Decommissioning Plan. On the basis of this EA, NRC has concluded that there are no significant environmental impacts and the license amendment does not warrant the preparation of an Environmental Impact Statement.

The NRC staff is considering preparation of a finding of no significant impact (FONSI). The following statements support a FONSI and summarize the conclusions of the draft EA.

> The Soil Decommissioning Plan, which will utilize surface remediation and in-place stabilization, provides a reasonable assurance that its measures will contain the radiological hazards for 1000 years. This plan is one component of the overall site decommissioning plan. The purpose is to provide a plan for the remediation of the windblown tailings, effluent contaminated soils, and soils contaminated by license activities that originated from the milling operation and disposal area. Further, it will allow the licensee to demonstrate that the cleanup plan was successful in remediating the contaminated soils to comply with the proposed release criteria. Staff finds reasonable assurance that the applicant has met its responsibilities under the provisions of 10 CFR Part 40 and will recommend approval the plan.

LIST OF PREPARERS

This EA was prepared by Michael Raddatz, Project Manager, Fuel Cycle Facilities Branch, Division of Fuel Cycle Safety and Safeguards, Office of Nuclear Material Safety and Safeguards.

REFERENCES

NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated With NMSS Programs - Final Report," Nuclear Regulatory Commission, Washington, DC, 2003.
[ADAMS Accession No. ML031000403]

NUREG-1620, Rev. 1, "Standard Review Plan for Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978," Nuclear Regulatory Commission, Washington, DC, 2003.
[ADAMS Accession No. ML040560561]

Rio Algom Mining LLC, 2004, "Soil Decommissioning Plan," submitted under cover letter dated January 19, 2005.
[ADAMS Accession No. ML050400566]

Rio Algom Mining LLC, 2005, "Response to Request for Addition Information for Soil Decommissioning Plan and the Closure Plan - Lined Evaporation ponds for Ambrosia Lake Facility," submitted June 15, 2005.
[ADAMS Accession No. ML052060155]

Rio Algom Mining LLC, 2005, "Response to Request for Addition Information Items 6, 9, and 13 for the Soil Decommissioning Plan and the Closure Plan - Lined Evaporation ponds for Ambrosia Lake Facility", submitted July 15, 2005.
[ADAMS Accession No. ML052090175]

Rio Algom Mining LLC, 2005, "Response to July 21, 2005 Request for Addition Information for the Soil Decommissioning Plan and the Closure Plan - Lined Evaporation ponds for Ambrosia Lake Facility," submitted September 27, 2005.
[ADAMS Accession No. ML053000439]

U.S. Fish and Wildlife Service. Letter to M. Raddatz dated October 31, 2005.
[ADAMS Accession No. ML052910059]

Data Recovery Plan For IA 82634 and IA 82635 at Rio Algom Mine, Near Ambrosia lake, McKinley County, New Mexico dated December, 2005
[ADAMS Accession No. ML060670532]

Comments Received on Draft EA		
AGENCY	**COMMENT**	**RESPONSE**
NMED - Received April 24, 2006 via E-Mail Comment 1	NMED recommends that the Plan provide details about the extent of excavation and removal of contaminated soils, such as a specified maximum depth or minimum concentration.	RAM has provided depth and concentration clean-up criteria for radiological constituents in surface soils in Section 5.1 and Table 5-1 of the Consolidated Plan. The typical excavation depth in areas associated with windblown deposited tailings is less than six inches (Plan Section 7.1.1). For areas of deeper soil contamination, Alternate Release Criteria have been applied as described in Section 5.2 based on site-specific dose modeling. Regardless of these specific criteria, excavation and removal of contaminated soils will not proceed beyond bedrock depth.

Comment 2	NMED recommends that the Plan propose a minimum thickness of 3 feet of clean fill material (e.g. unimpacted Mancos Shale) that will cover any area identified with deeper soil contamination that will not be removed.	RAMs design criteria was based not only on assuring protection of human health and the environment but the Plan also achieves long term stability of the site. RAMs design objective was to preclude the need for on-going maintenance of the design elements. The current design will provide positive drainage in this area. Placement of superfluous soils over these areas would change the geomorphic profile of the area by creating topographic highs and potential water collection areas resulting in on-going maintenance requirements associated with wind/water effects. RAM has performed site-specific dose modeling in areas of deeper soil contamination and applied appropriate cover thicknesses to ensure protection of human health and the environment as measured by compliance with the benchmark dose. Further, long-term erosion modeling (Attachment B of the Consolidated Plan) has led RAM to propose application of a gravel mulch to the surface of evaporation ponds 4 through 8 to ensure stability of the cover, as described in Section 8.2.2 of the Consolidated Plan. Approval of the Alternate Concentration Limits for the Ambrosia Lake incorporated NMED concerns and addressed potential surface and groundwater impacts attributable to licensed material.
Comment 3	NMED recommends that the Plan propose surface grading designs to provide positive drainage away from covered areas with contaminated soils.	Please refer to response to NMED Comment #2. The Soil Plan is one component of the overall site closure process. Surface drainage features have been incorporated into the overall plan to ensure site stability and preclude on-going site maintenance. The purpose of these design features, which include diversion channels, surface grading, and placement of erosion protection, is to manage and control surface water from impacting the long term stability of the site.

Comment 4	NMED recommends that non radiological contaminants such as chloride, sulfate, nitrate, total dissolved solids, and other parameters be considered in the cleanup criteria when assessing areas with soil contamination. In the form of Rio Algom Mining LLC License SUA-1473 -- Docket 40-8905 leachate in contaminated soils, both the radiological and non radiological contaminants may move directly or indirectly into groundwater, and many of the non radiological contaminants may travel a greater distance in the subsurface than the radiological parameters.	The typical excavation depth that RAM will utilize in areas associated with windblown deposited tailings is less than six inches. This excavation depth will be successful in removing both the radiological byproduct material as well as the non-radiological byproduct material. More importantly, approval of the Alternate Concentration Limits for the Ambrosia Lake incorporated NMED concerns and addressed potential surface and groundwater impacts attributable to licensed material.

Paleo channel

Appendix E.. Geomorphic Evaluation

512-897-3712

Appendix E.1 .... <u>Geomorphic Technical Evaluation Report</u>

<u>Geomorphic Evaluation of Arroyo del Puerto Drainage</u>
<u>Ambrosia Lake Area</u>

Evaluation Prepared by Jerry Lindsey
AMEC

July 2007

Geomorphic Evaluation of Arroyo del Puerto Drainage
Ambrosia Lake Area

Prepared By:

Jerry Lindsey
AMEC
July 2007

Geomorphic Setting

The Rio Algom Mining LLC Ambrosia Lake site is located in Section 31, T 13N, R9W in Ambrosia Lake valley, New Mexico. The valley trends with the strike of the Cretaceous formations at the south edge of the San Juan Basin with strata dipping about 2 degrees northeast into the basin. Resistant strata of the Mesa Verde Group forms a high cuesta, called San Mateo Mesa, on the northeast side of the valley and lower Cretaceous strata of the Dakota and resistant sandstone members of the Mancos Shale form a similar cuesta, Mesa Montanosa, on the southwest side to bracket the valley. The valley has a width of about 7 km (4.3 miles wide) and slopes to the southwest at 1.1 degrees, the opposite direction of the dip of the strata. The Arroyo Del Puerto follows the southwest side of the valley, and trends southeast toward the confluence with San Mateo Creek at the southeast end of the valley eventually converging with the Rio Puerco about 65 km (40 Miles) southeast of the site. The San Mateo Creek flows south across a broad valley through the Homestake uranium mill and tailings site where the slope of the drainage ranges from .005 to .003 in near playa conditions. Protection against erosion there would prevent migration of nick points upsteam that might destabilize the Arroyo Del Puerto.

Mining and milling of uranium ores began in the late 1950's and early 60's resulting in some diversion of local drainage to protect tailings piles and mine. As many as 24 mines were operating in the valley at one time operating at depths from 170 to 450 m (560 to 1500 feet) depths (DOE, UMTRA, 1990). The Phillips-United mill and tailing site in section 28 has been remediated (DOE UMTRA -1990) and the Rio Algom milling site is in closure action in accordance with Nuclear Regulatory Commission criteria. All the underground mines have been filled and stabilized.

The valley has no native trees and presently has a moderate cover of native grass. Cattle grazing is the main use of the land in the upland part of the basin. There is no agricultural use of the land. As a policy, the USDA and State Soil Conservation has not made soil maps of the valley because of its previous use for mining and milling of uranium (USDA web site). Regionally, the age of deposition of the oldest Holocene alluvial and eolian units has been estimated to be between 2,500 to 7,000 years old and the youngest developed soils are estimated are no greater than 2,300 years based on soil development and radiocarbon dates (Wells et al, 1983). A map of the valley and location of the Rio Algom site is shown in Figure 1. The map shows 1957 drainage with mines and mill locations photo-revised to 1980.

The geomorphic processes upgradient from the site consist of sheet flow and ephemeral channel flow, and wind erosion and eolian deposition. Mine dewatering has occurred as recently as 2005 utilizing pipelines, treatment ponds and infiltration system rather than overland flow. A secondary process is the high infiltration rate of the thick surficial alluvial deposits that significantly reduces the potential for gullying. The drainages throughout the lower valley are poorly defined however one area in the upper portion of the drainage basin shows severe gullying of playa type soils, with piping and caving of banks. The incised drainage was down stream from a breached cattle pond with slopes ranging from 0.02 to .04 ft/ft. This area is in section 18, 4 - km (2.5 miles) north of the project site. This condition was also observed during restoration of the Phillips-United mill and tailing site (DOE, UMTRA, 1990).

<u>Valley alluvium and basin slopes</u>

The lack of gullying in the lower Ambrosia Lake valley has been described in the remediation of the nearby Phillips-United tailings pile in Section 28 (DOE, UMTRA, 1990), which observed that highly permeable surface materials have resulted in rapid infiltration rates with very little surface runoff. Directly upslope from the Arroyo Del Puerto drainage in the northeast quarter of section 31 where the diversion channel is proposed the slope progressively decreases from .0175 to .0155, to .010 ft/ft over a distance of one mile. The high Infiltration rate should be considered in the channel design for PMF storm event.

The Arroyo Del Puerto is the only well defined channel in the lower part of the basin. Tributary channels are poorly defined as a result of a lack of flow concentration caused by infiltration and dissipation of runoff. Encroachment of the arroyo against the resistant bedrock outcrops is the cause of flow concentration and channel development along the course of the drainage.

The soil associations mapped by the Soil Conservation Service (1967) indicates that the lower part of the valley adjacent to the Arroyo Del Puerto is the Lohmiller-San Mateo soil association. This map, presented in DOE, UMTRA (1990), is shown in Figure 4. The soil is described as derived from sandstone and shale bedrock, about 60- inches (150- cm) deep and consists of loam, clay loam, sandy loam and clay and is often stratified. This soil series is not defined in nearby basins by more recent Soil Conservation soil map (USDA website). Observation of this mapped area indicates that it was intended for basin fill slopes of 0.015 ft/ft or less in the lowest part of the valley bordering Arroyo Del Puerto, and has very little clay content. An example of this slope under relatively undisturbed conditions is shown in Figure 5 (Photo No. 5). There is no apparent development of clay crusts that would promote runoff as consequence of lack of intense rainfall to develop the crust, and perhaps lack of available clay in the upper 2-cm as indicated by Duffy and Gardner (1983). Impact of rainfall may be inhibited by moderate to sparse vegetation cover.

The orientation of Ambrosia Lake valley, northwest to southeast, is considered favorable for deposition of windblown dust from prevailing southwest and westerly winds, as a result of its high cliff faces on the southwesterly cuesta escarpment. A high percentage of reworked eolian material would explain why the alluvium has a higher permeability rate than would occur by sediment derived from bedrock highlands alone.

In the adjacent Chaco Canyon basin, Duffy and Gardner (1983) observed that typically deep and well vegetated eolian deposits which blanket the bedrock and uplands surfaces are less prone to erosion. Studies have shown a strong correlation between less permeable soils and increased ephemeral discharge and the relevance of infiltration behavior in examination of the overland flow process. Rapid incision is predominantly associated in Chaco Canyon with valley fill deposits where valleys are drained by a central channel. Such erosion can be the result of: man induced changes, primarily mining and overgrazing; secular climatic variations in rainfall; and changes in rainfall distribution. In San Juan basin the impact of these factors is seen as reduced infiltration where channeled flow predominates. Recent studies of soils in a semi-arid climate conclude that porosity, texture of top 7 centimeters, the percent of bare surface, and the percent of crown cover are the predominant factors influencing infiltration characteristics. (Duffy and Gardner, 1983).

A map of the drainage basins, provided by Tetra Tech, shows that the slopes in subbasin 4B directly upslope north of Pond No. 1, are less than .010 ft/ft (1.0 percent) over a linear distance of 4,570 m (14, 990 feet), and 4,865 (15,964 feet) measured along the thalweg center of drainage. The lowest slope measured is 0.005 or ½ percent grade. This area of 1.0 percent (or less) slope provides a buffer area around the north side slope where drainages are poorly defined and infiltration is most likely to occur before entering the flow concentration of the diversion channel. The slopes on the north 60 percent of the basin reach gradually increases to a maximum of 0.032 near the drainage divide a distance of 10.2 km (6.3 miles) from the diversion channel at the north site boundary of Section 31. Sub-basins 4C and 4D are shorter and have higher slopes on the flanks of San Mateo Mesa but the "buffer" zone near the site shows similar low slopes. This zone, directly upslope of the proposed Option 2 diversion ditch that delineates an area where the slopes are less than 0.013 is shown on Figure 6. The area is characterized by poorly defined channels, deposition exceeds erosion, and infiltration is expected to have a substantial influence on runoff contributions to Arroyo Del Puerto. The channel of Arroyo Del Puerto becomes recognizable only where it is adjacent to bedrock outcrops or where the runoff from bedrock is more appreciable than in the valley basin areas.

Rio Algom Site Area

The area around the Rio Algom site is shown in Figure 2. The original channel of Arroyo Del Puerto (blue) goes across the site from northwest to southeast with the lower portion of the channel offset by construction of Tailings Impoundments 1 and 3. The original channel was essentially the boundary between bedrock (southwest) and alluvium (northeast), except where lateral drainages joined the arroyo. A mine water discharge ditch was constructed which was also used to divert potential flows in the arroyo around the site (green). Under Option 2, potential flows in the Arroyo Del Puerto would be diverted by placing a diversion channel with the berm upslope of former waste ponds 4, 5, and 6 starting at the northwest approach of the original channel to the site. The outlet of the diversion channel would be to the Arroyo Del Puerto channel adjacent to Pond 9 (just off of Figure 2 to the south). The approximate berm location is shown by cross-hatching; its channel will have an approximate average slope of 0.05 ft/ft.

Arroyo Del Puerto enters the site from the west where it crosses the Rio Algom Access Road. Figure 3 (Photo No. 1) shows the down stream channel and the pipeline that was apparently used to import mine water to the treatment ponds prior to being discharged in the infiltration ditch. Immediately west of that crossing, two shallow tributaries are indicated on the topography map from the north and south to converge on the main drainage. There is little evidence of these tributaries today. The channel of Arroyo del Puerto is a vegetated swale about 3 feet deep and is free from gully incision. The lower reach of this drainage has been diverted from its original course by the construction of the infiltration ditch. The original drainage meandered between the two largest waste piles and cut off the northeast 1/4 of section 31.

Mine water discharge was a factor in creating bank erosion of channels in adjacent basins as reported by Mills and Gardner (1983). The history of dewatering of the mines is not well known across the valley here but the mine water discharge upstream from the site has evidence the water was piped to treatment ponds rather than being released into drainages.

<u>Mine Water Discharge Ditch</u>

In order to restrict the ground water contaminants from migrating north and east of section 31, a ditch was dug on the north and east boundaries of section 31 to maintain a "water mound" of perched contaminants towards the interceptor trench at the toe of Pond 3. The ditch is indicated in Figure 2 showing the point of discharge. The mine pumping at section 30 West stopped in December 2005, and the ditch pumping stopped in early 2006 with intermittent pumping through 2006. On the north side near the discharge the water level was within 5 feet of the surface. The water level declined to a current depth of 36 feet in well 31-05 when pumping ceased at the end of 2006.

A footprint of the recharge mound indicated that the mound was spread around the north side ditch as far as 520 m (1700 feet) but dissipated rapidly on the southward leg. (Maxim, 2001). This methodology illustrates both the infiltration capacity of the alluvium and the storage capacity of an underlying paleochannel to handle large quantities of surface water infiltration.

The infiltration ditch along the north side section line is about 3 feet deep and is shown in Figure 7 (Photo No. 3). The ditch on northeast section line was dug to about 8 feet below natural grade. Presently a portion of the original arroyo channel is being excavated to remove contaminated soils and the excavation reveals the sandy silt, as shown in Figure 8 (Photo No. 2) that is typical of the upper 37 feet of this alluvial deposit. A grain size analysis shows 100 % passing the No. 40 sieve and 51 to 67% passing the No 200 sieve resulting in a soil classification as a fine sandy silt. A borehole log of well no. 31-05 at the northeast corner section 31 shows 37 feet of this sandy silt, called "blow sand" underlain by another 41 feet of mostly sand and fine gravel with minor lenses of sandy clay. The gravelly alluvium is not locally seen but was noted in some terrace deposits in Section 28 near an older channel (DOE, UMTRA, 1990) and was thought to be derived from the Gallup Sandstone that outcrops in San Mateo Mesa to the northwest. In the Groundwater ACL Application for Rio Algom (Maxim, 2001), approved by the NRC, the alluvium was modeled using a hydraulic conductivity of 18 ft/day (or approximately 1 X 10^{-2} cm/sec).

Arroyo Del Puerto Paleochannel

The existence of the paleochannel in the valley alluvium is apparent from the migration of drainage down slope toward the southwest impinging against the resistant bedrock benches that underlie the main waste pile and Rio Algom facilities. This was also documented by Kerr-McGee Nuclear Corp (1980) and referenced by DOE UMTRA

(1990) as shown in the cross section in Figure 9. This paleochannel is an ancestral drainage of the Arroyo Del Puerto. An isopach map that defines a paleochannel in the Phillips/United mill tailings pile (DOE, UMTRA, 1990) in section 28, shown as Figure 10, upslope from the Rio Algom main pile, indicates a channel incised in the bedrock trending southwest. The trend would make it a tributary to the main southeast trending paleochannel in south ½ of section 32. This suggests that it is likely there are other lateral tributaries incised in the Mancos Shale bedrock surface to form an under drain for the valley. One account reported an alluvial thickness of 100 feet near the Arroyo Del Puerto (Purtymun et al, 1977).

Bedrock Outcrops

The bedrock benches on the high ground immediately bordering the south side of Arroyo Del Puerto as defined by topographic contours shown in Figure 2, form the foundations for Pond 9 and the former Rio Algom facilities. Figure 9, cross section shows the resistant sandstone members of the Mancos Shale called Tres Hermanos (C) and Tres Hermanos (B) with interbedded shale forming the outcrops. The upper portion of Figure 9 shows the outcrops with respect to outline of Tailings Impoundments 1 and 3. A photograph of typical bedrock outcropping, in the south half of section 31 (north of Tailings Pond 1) is shown in Figure 11 (Photo No 4). This high ground is an erosional feature resulting from channel development of the ancestral arroyo that formed the paleochannel and the present day drainage impinging against the resistant outcrops.

Conclusions

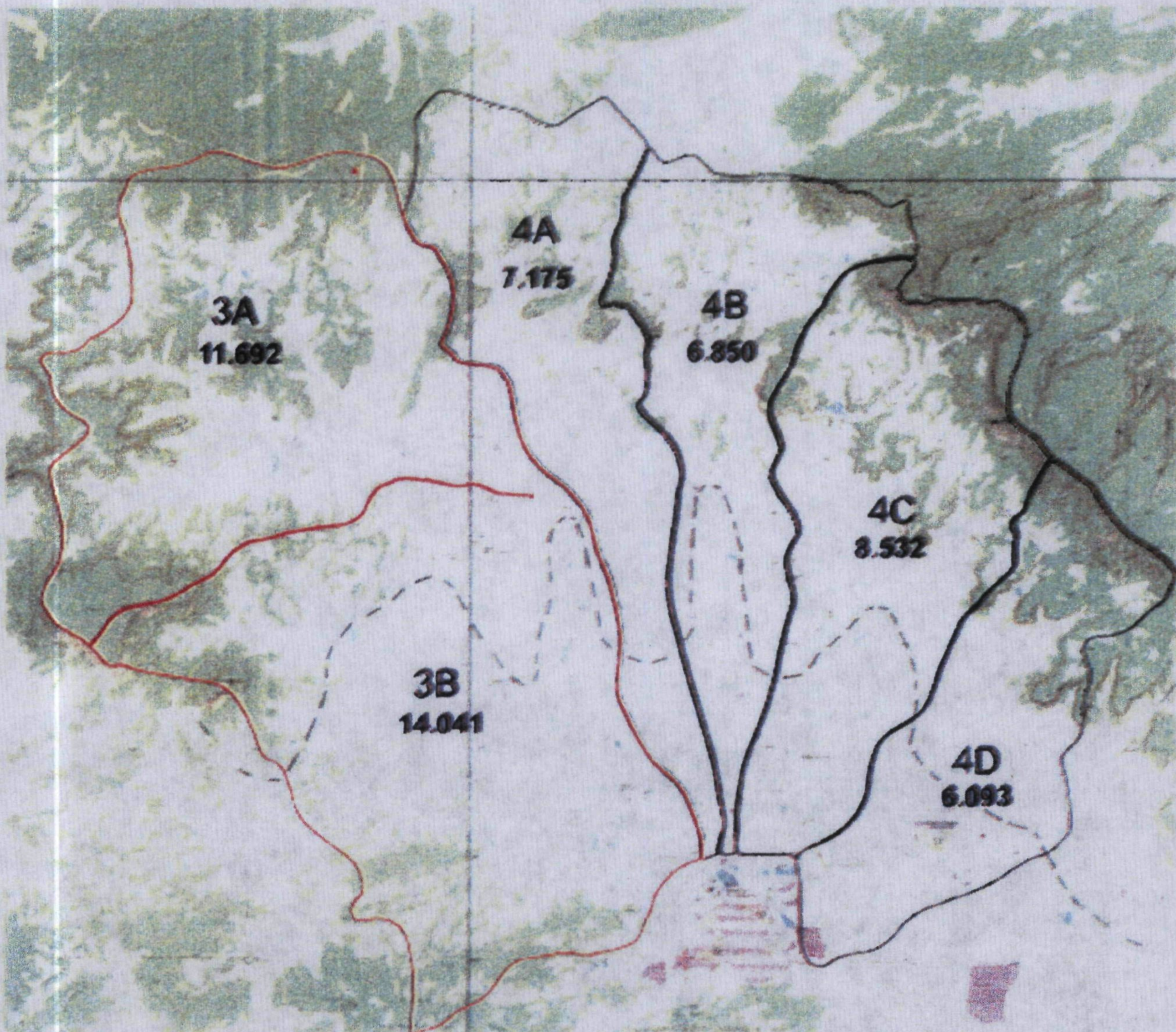
The geomorphic processes that most affect the Option 2 plan appear to be mitigating factors for supporting the stability of the proposed diversion channel. The lack of gullying in the most prominent drainages is a result of a high infiltration rate because of low slope gradients and deep permeable soils. The potential for infiltration is matched by a high capacity of storage evident by the granular fill in the underlying broad paleochannel. It is expected that infiltration could result in a substantial loss of runoff for a PMF.

The fine grained, low plasticity soils in which the channel is founded may result in local minor sedimentation that could mostly fill the interstices of the rock erosion protection but as a consequence of its fine grain and lack of cohesion/cementation should be of negligible consequence to any significant run-off event. It is unlikely that sedimentation of native coarse sand or gravel that might form deposits resistant to runoff will occur since there are no sources for such material.

Sedimentation of Arroyo Del Puerto valley has been in progress for at least 2500 years. Long term geomorphic stability of the valley is dependent on the stability of San Mateo Creek down stream from the site, is in near playa conditions. The stability of that valley has an added protection with the clean-up conditions of the Homestake mill and tailings site.

Photo No. 3 Looking east from haul road, north boundary line Section 31

FIGURE 7 INFILTRATION DITCH USED FOR WATER MOUNDING



Numbers indicate area size in square miles

= approximate boundary where slope is less than .013 approaching intercept diversion channel. This defines an area where drainage is poorly defined and infiltration into deep alluvial deposits is at a maximum.

FIGURE 6 DRAINAGE BASINS FOR RIO ALGOM SITE

Photo no. 5, looking south toward Arroyo Del Puerto drainage
Slope is 0.010 ft/ft (1.0 Percent)

FIGURE 5 TYPICAL SHEET FLOW SLOPE UPGRADIENT FROM PROPOSED DIVERSION CHANNEL

SOIL ASSOCIATIONS

1 LAS LUCAS–LITLE–PERSAYO

2 LOHMILLER–SAN MATEO

3 ROCK LAND–TRAVESSILLA

4 ROCK LAND–BOND

5 HAGERMAN–TRAVESSILLA

Reference: U. S. Soil Conservation Corp.

FIGURE 4 SOIL MAP OF AMBROSIA LAKE VALLEY, NEW MEXICO

(PHOTO NO 1)

FIGURE 3 VIEW OF ARROYO DEL PUERTO LOOKING EAST FROM RIO ALGOM ACCESS ROAD

- Arroyo del Puerco
- infiltration ditch for water mounding

Note: locations of photographs are indicated by arrows
Note: The lower reach of Arroyo Del Puerto as shown has been straightened and moved east from bedrock encroachment.

FIGURE 2 SITE PLAN SHOWING PROPOSED OPTION 2 DIVERSION CHANNEL

Reference: USGS topographic map, Ambrosia Lake Quad.
1957, photo enhanced 1980.

FIGURE 1 RIO ALGOM SITE IN AMBROSIA LAKE VALLEY, NEW MEXICO

References

Duffy, W. D. and Gardner, T. W., Soil Characterization, headcut erosion, and Landsat classification in the San Juan Basin; IN Wells, W.D., Love, D. W. and Gardner, T. W., eds., Chaco Canyon, a field guide to the geomorphology, Quaternary geology, paleoecology and environmental geology of Northwestern New Mexico: American Geomorphological Field Group, 1983 Field Trip Guidebook,

Kerr-McGee Nuclear Corp., 1980; IN Bostic, K., 1985, Ground-water discharge plan analysis for Kerr-McGee Nuclear Corporation, Ambrosia Lake Uranium Mill, Quivira Mining Company, Draft Report--Ground water Section, Ground Water Quality and Hazardous Waste Bureau, New Mexico Environmental Improvement Division, Santa Fe, New Mexico

Maxim Technologies, Inc., 2001, Application for Alternate Concentration Limits in the Alluvial Materials at the Quivira Mill Facility, Ambrosia Lake, New Mexico.

Mills, A. M., and Gardner, T. W., 1983, Effects of aquifer dewatering on an ephemeral stream in San Juan Basin, New Mexico; In Wells, W.D., Love, D. W. and Gardner, T. W., eds., Chaco Canyon, a field guide to the geomorphology, Quaternary geology, paleoecology and environmental geology of Northwestern New Mexico, American Geomorphological Field Group, 1983 Field Trip Guidebook,

Purtymun, W. D., Wienke, C. L. and Dressen, D. R., 1977, Geology and hydrology in the vicinity of the inactive mill tailings pile, Ambrosia Lake, New Mexico, UC-11; Informal report LA-6839-MS, Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico.

US Dept. of Energy, UMTRA, 1990, Remedial action plan and site conceptual design for stabilization of the inactive uranium mill tailings site at Ambrosia Lake, New Mexico, UMTRA-DOE/AL 050516.0000

USDA Soil Conservation Service, 1967, Soil association map (reprinted in DOE, UMTRA, 1990) (Reference not confirmed)

Wells, S. G., Bullard, T. F., Smith, L. N., and Gardner, T. W., 1983, Chronology, rates, and magnitudes of late Quaternary landscape changes in the Southeastern Colorado Plateau. ; IN Wells, W.D., Love, D. W. and Gardner, T. W., eds., Chaco Canyon, a field guide to the geomorphology, Quaternary geology, paleoecology and environmental geology of Northwestern New Mexico: American Geomorphological Field Group, 1983 Field Trip Guidebook.

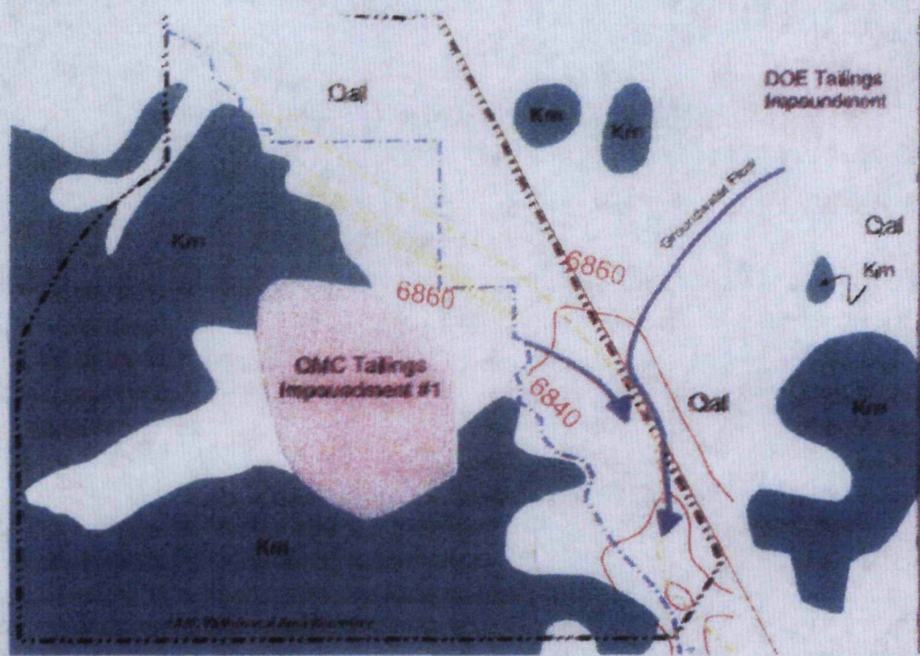
Photo No. 2, looking northeast

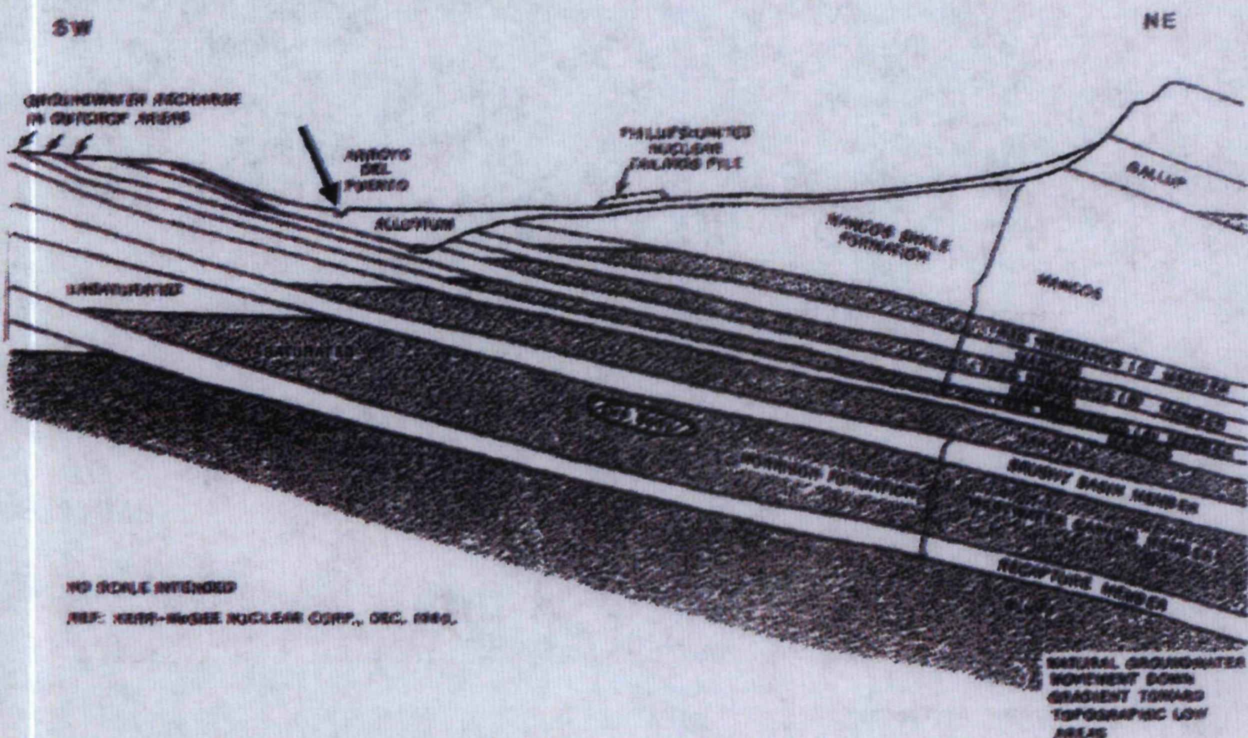
FIGURE 8 EXCAVATION OF CHANNEL OF ARROYO DEL PUERTO SHOWING SANDY SILT ALLUVIUM

Modified from: Maxim

Simplified geologic map of QMC Site showing contours of paleochannel

0 1/2 mile

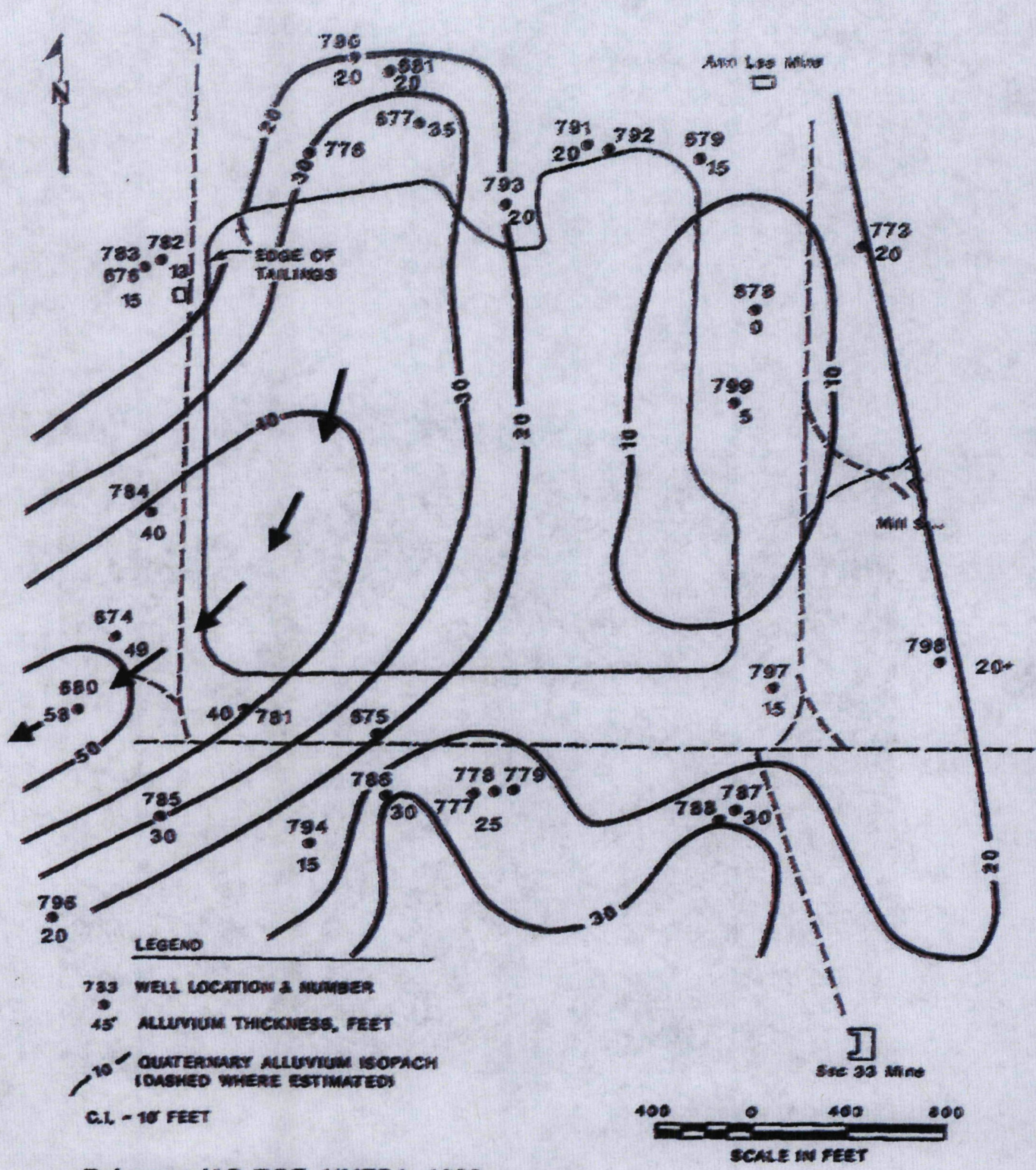




FROM: DOE, UMTRA, 1990

This section shows strata underlying the Rio Algom site and the paleochannel that underlies the Arroyo Del Puerto

FIGURE 9 GEOLOGY MAP OF SITE AREA AND CROSS SECTION OF VALLEY



Reference: U.S. DOE, UMTRA, 1990

FIGURE 10 ISOPACH MAP OF PALEOCHANNEL INCISED IN MANCOS SHALE

Photo No 4, looking east

FIGURE 11 SANDSTONE-SHALE BEDROCK ON HIGH GROUND ABOVE ARROYO DEL PUERTO

REFERENCES

22-25

Section 27 Mine Stage I Abatement Investigation Report

Ambrosia Lake Valley, New Mexico

Prepared for:

United Nuclear Corporation

Prepared by:

INTERA Incorporated

Submitted To:

New Mexico Environment Department
Ground Water Quality Bureau
Mining Compliance Division

November 5, 2007

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Appendix A	Section 27 Mine Stage 1 Abatement Plan Proposal
Appendix B	Field Notes
Appendix C	Troll Water Quality Profile Data for Section 27 Vent Holes
Appendix D	Analytical Laboratory Report and Chain of Custody Records for Vent Hole Samples
Appendix E	Summary Statistics for Westwater Canyon Database
Appendix F	Box-and-Whisker Plots
Appendix G	Histograms
Appendix H	Probability Plots
Appendix I	Time Series and Hydrographs

1.0 Introduction

In January 2007, INTERA Incorporated (INTERA) was retained by United Nuclear Corporation (UNC) to complete the requirements of the Section 27 Mine Stage 1 Abatement Plan (Stage 1 Plan) (Montgomery Watson Harza [MWH], 2006). The Section 27 Mine Stage 1 Abatement Investigation Report (Stage 1 Report) provides the methodologies, results, and conclusions developed by INTERA for the Stage 1 Plan. A site location map for the Section 27 Mine is provided as Figure 1-1.

The following key observations led to the development of the conclusions of this report. These are discussed in detail in subsequent sections of the report, but are presented here to facilitate the reader's understanding of primary themes.

1. A regional cone of depression resulted from the dewatering of uranium mines within the Westwater Canyon Member of the Morrison Formation in the vicinity of Ambrosia Lake Subdistrict of the Grants Uranium District. Bedrock units in the Ambrosia Lake Valley were essentially dewatered in the vicinity of the mines by pumping that began in the late 1950s. Since most dewatering was discontinued in 1986, water levels in these units have been recovering as ground water flows back into the dewatered areas from the surrounding region. Estimates of the amount of time required to repressurize the regional cone of depression range from several hundred to several thousand years (Bostick, 1985).

2. Mine workings in the Ambrosia Lake Valley are interconnected over an area approximately 10 miles long and 2 miles wide, providing preferential flowpaths such that it cannot be assumed that the movement of ground water is perpendicular to equipotential lines. Due to mine dewatering, ground water is and has been in a transient state since the onset of mining. Flowpaths have and will continue to change over time and thus, the concepts of upgradient and downgradient alter through time, making the precise source of any particular constituent indeterminable. In Section 2, we present maps of the potentiometric heads in the Westwater Canyon Sandstone at five specific points in time to show the variability of ground water flow over the last 25 years.

3. Consideration of basic principles of geology, hydrology, and geochemistry suggest that large water quality variations are possible over very small distances in and near uranium ore deposits in the Westwater Canyon Sandstone. Section 3 summarizes the extensive literature review and basic concepts that support variability of ground water quality in the Westwater Canyon Sandstone. Ground water quality variability is also supported by vertical profiling of vent holes at the Section 27 Mine, which is discussed in Section 2. An understanding of ground water variability is important because it attests to the non-equilibrium state of the geochemical system (in addition to the hydraulic part of the system), and constrains potential remedial options.

4. Given the changes in flow direction over time, and the number and complexity of geologic and geochemical variables that can influence ground water quality, temporal water quality trends are evident in data from samples of ground water in mine shafts and vent holes that penetrate the Westwater Canyon Sandstone in the Ambrosia Lake Valley. Mine dewatering exposed previously unoxidized uranium ore deposits to atmospheric oxygen, resulting in oxidation of ore materials and chemical reactions that degrade water quality (Section 4.2). Over time, repressurization will fill mine voids with ground water and remove the source of atmospheric oxygen, resulting in improved ground water quality and a return to pre-mining geochemical conditions in the Westwater Canyon Sandstone. Time concentration plots discussed in Section 3.3.1.5 provide evidence that, at many locations, the impact of mine dewatering has peaked and water quality is improving. As expected, improvements are most apparent in locations where the mine workings are already flooded.

The ultimate importance of the observations outlined above is to support the principle that the ground water quality issues in the Ambrosia Lake Subdistrict must be viewed as a whole. Ignoring the interconnected nature of mine voids in the Ambrosia Lake area by focusing on the Section 27 Mine investigation results in isolation may lead to erroneous conclusions.

1.1 Background

The Section 27 Mine is an underground uranium mine in southern McKinley County (Figure 1-1) that was operated in the 1970s by UNC, pursuant to a mineral lease. UNC closed the mine in the late 1980s and conducted reclamation activities on all of its nearby private land holdings. The lease was surrendered in 1988 and closure activities were conducted that same year; however, the owner of the Section 27 leased land did not give UNC permission to conduct reclamation on the leased areas.

On September 1, 2004, the New Mexico Environment Department (NMED) Ground Water Quality Bureau (GWQB) issued a letter to UNC requesting a Stage 1 Abatement Plan Proposal for the Section 27 Mine (Site) in accordance with 20.6.2.4106 New Mexico Administrative Code (NMAC). The following issues were identified in the NMED letter and in personal communications with NMED (MWH, 2006):

- Potentiometric data in the Groundwater Quality Technical Memorandum (MWH, 2004) may not represent current conditions at the Site.
- Additional data and analyses are required to demonstrate current water quality conditions in the Westwater Canyon Member at the Site.

UNC submitted a draft Stage 1 Plan to NMED in November 2005 and NMED responded to this draft with the following comments:

- The basis and purpose of the Stage 1 Plan must be to assess current ground water conditions.
- Section 20.6.2.4103.C NMAC requires surface water to be included.
- Ground water sample collection needs to be performed in all three vent holes (VHs).
- Purge water cannot be put back into the vent holes.
- A more specific materials characterization plan needs to be included.

UNC responded to these issues and developed the final *Section 27 Mine Stage 1 Abatement Plan Proposal (Stage 1 Plan), September 2006* (MWH, 2006). On October 13, 2006 NMED conditionally approved this Work Plan on the following conditions:

- Additional site characterization activities may be required if sufficient data are not collected to allow for the identification of the extent and magnitude of the ground and surface water quality conditions as well as characterization of the hydrogeology of the Site.
- All data generated from the materials characterization is to be included in the Stage 1 Plan.
- Reduction/oxidation potential (Eh) and dissolved oxygen (DO) must be included in the field parameter list and measurement of these parameters must occur at all sampling locations.
- Total suspended solids and manganese need to be added to analyte list.
- The Stage 1 Plan shall include the following:
  - Water sampling logs
  - Survey data including reference points for vent holes/shafts, elevations and coordinates, and water table elevations
  - Site map with sampling locations and a water table elevation map
  - Analytical data including soil sample data and ground water analyte concentration data (including copies of the original laboratory data sheets)
  - Short description of field activities conducted to that point including observations noted during sampling activities and an interpretation of the geology and the hydrology of the Site
  - Discussion of assessment activities including any findings and interpretation of the data collected

All of NMED's issues and requirements are addressed in this report with the following exceptions:

- *Section 20.6.2.4103.C NMAC requires surface water to be included.* There is no surface water in the vicinity of the Site; therefore, no surface water samples were collected.
- *A more specific materials characterization plan needs to be included.* NMED has been provided a copy of the Section 27 Materials Characterization Plan by the Mining and Minerals Division (MMD) of the New Mexico Energy, Minerals and Natural Resources Department (NMEMNRD).
- *All data generated from the materials characterization is to be included in the Stage 1 Plan report.* As agreed to by the NMED Section 27 Project Manager, Mr. Jerry Shoeppner, the materials characterization data will be provided in a separate report that will be made available to NMED.

1.2 Site Description

The Site is located in the southern half of Section 27, Township 14 North, Range 9 West, approximately 35 miles north of Grants, New Mexico. The mine lies within the Ambrosia Lake Valley, a broad, elongate valley that was once the site of some of the most productive uranium mines in the U.S. and remains undercut by layers of mine workings. The Site is located approximately 1 mile east of the Phillips Petroleum Ambrosia Mill Site and numerous decommissioned mines and mills as well as ore and tailings piles are located within a 7-mile radius (Figure 1-1).

As illustrated on Figure 1-2, the Site contains a number of features; those important to this Stage I Plan include:

- Two vent shafts
- Three vent holes
- Two small piles of non-economic mine materials (overburden rock)
- Sand and gravel
- One small ore stockpile
- Two topsoil stockpiles
- Several small piles of ball mill reject materials

The Site is currently inactive and encompasses approximately 14 acres. The surface rights are currently held by Kent Schmitt and Hecla Mining Company owns the mineral estate (MWH, 2006). The Site is surrounded by numerous former mine sites and a mill site. Mine workings are known to be connected from one end of Ambrosia Lake Valley to the other.

1.3 Site History

Mining began at the Section 27 Mine in 1966 with the sinking of Shaft no. 1 and was accomplished by conventional room and pillar methods. UNC produced uranium ore from the Site from 1970 to 1977 (MWH, 2006). Mining was fully suspended by 1980.

UNC closed the mine in the late 1980s in accordance with requirements of the mining leases and mine safety regulations. The closure activities included the removal of stockpiled ore, buildings and machinery, and the sealing of shafts and vents. UNC also conducted voluntary reclamation activities at the nearby Sandstone Mine and all of UNC's land holdings in Section 27. On the leased lands where the Site is located, UNC was not given permission by the landowner to perform similar reclamation activities.

The mineral lease that included the Site area covered approximately 200 acres in the south half of Section 27; the lease was sold in 1988. Surface ownership at the mine is currently held by Kent Schmitt. Ownership of the mineral estate is held by Hecla Mining Company (MWH, 2006).

1.4 Site Conceptual Model

1.4.1 Physiography and Climate

The Section 27 Mine lies on the southern edge of the San Juan Basin portion of the Colorado Plateau, a large physiographic feature that dominates the four-corners region of the southwest. It lies within the Ambrosia Lake Valley and the Arroyo del Puerto drainage basin.

The regional climate is classified as semiarid and continental; site-specific climate data are not available. The Ambrosia Lake Valley area typically has large diurnal temperature variations with a mean daily average temperature in San Mateo, NM of 49.2 degrees Fahrenheit (°F). Temperature varies with elevation, with typical winter values below 0°F and summer temperatures as high as 100°F.

Regional precipitation also varies with elevation, ranging from less than 10 inches per year in the valleys to over 20 inches per year at the summits. Summer precipitation typically falls during short-duration, high-intensity thunderstorms. In winter, precipitation generally falls as snow. The mean annual lake evaporation for the area is 54 inches.

Winds blow predominantly from the west and north-northwest. The average wind speed for all wind directions is 9.3 miles per hour.

1.4.2 Geology

The Site is located within the San Juan structural basin, which covers approximately 21,600 square miles primarily in northwestern New Mexico, with smaller portions in adjacent parts of southwestern Colorado and northeastern Arizona. It is about 140 miles wide and 200 miles long.

The basin is bounded by structural uplifts on all sides; sags in these uplifts are present in each of the basin's four corners. The structural center of the basin is located beneath the Navajo Reservoir in the northeastern part of the basin. Up to 14,400 feet of sedimentary rocks ranging in age from Devonian to Tertiary fill the basin (Craigg, 2001). These rocks dip into the basin relatively steeply on the north, west, and east margins of the basin and less steeply along the south margin. The older rocks crop out along the basin perimeter and are overlain by successively younger rocks toward the center of the basin. The surface in the central part of the basin consists of relatively flat-lying sedimentary rocks; portions of the basin are covered with alluvium and basalt flows (Figures 1-3 and 1-4).

1.4.2.1 Stratigraphy

The area of interest for this Stage 1 Report consists of sedimentary rocks of Upper Jurassic through Tertiary age, including the Morrison and younger formations. This section of the stratigraphic column, depicted on Figure 1-5, is up to approximately 8,500 feet thick. The following descriptions of the key geologic units that occur in the Site vicinity are taken primarily from more lengthy descriptions provided by Craigg (2001).

Morrison Formation. The Westwater Canyon and Brushy Basin are the uppermost two members of the Morrison Formation. The Westwater Canyon Member is present throughout the San Juan Basin at thicknesses that range from about 100 feet on the northern, eastern, and southern sides of the basin to about 300 feet in the southwestern-central part of the basin. It consists locally of conglomeratic sandstone interbedded with sandstone, shale, and claystone; the proportion of sandstone and the grain size of the sandstones decrease toward the northeast. The Brushy Basin Member, consisting mainly of calcareous and bentonitic claystone and mudstone, is also present throughout the basin. Its thickness ranges from about 80 to 250 feet and is commonly about 185 feet in the San Juan Basin. The Brushy Basin Member was removed from the southwestern corner of the basin by erosion that occurred before the deposition of the overlying Dakota Sandstone.

Dakota Sandstone. The Dakota Sandstone overlies the Morrison Formation throughout the San Juan Basin. It consists of a basal section of sandstone and conglomeratic sandstone overlain by a middle section of siltstone, shale, and lenticular sandstone beds and an upper section of fine-grained sandstone interbedded with shale. The Dakota Sandstone ranges from 10 to about 500 feet thick and is commonly 200 to 300 feet thick. The thickness generally increases from the northern and western margins of the basin toward the eastern and southern margins.

Lower Mancos Shale. The lower part of the Mancos Shale is present above the Dakota Sandstone throughout the basin, intertonguing with sandstone units of the Mesaverde Group at some locations. In the north, the main body of the Mancos Shale is up to about 2,300 feet thick. The aggregate thickness of the Mancos tongues in the southern part of the basin is about 1,000 feet. The Morrison Formation, Dakota Sandstone, and Mancos Shale are exposed in outcrop directly southwest of Ambrosia Lake Valley.

1.4.2.2 Mineral Deposits

The Site is located in the Ambrosia Lake Subdistrict of the Grants Uranium District. Uranium deposits in this district are part of the larger Grants Mineral Belt that extends for over 100 miles along the southern margin of the San Juan Basin (Figure 1-4). Ore deposits along this 10- to 20-mile-wide feature occur from the land surface to depths of over 4,000 feet (Chenoweth, 1977). These deposits are irregular in shape and range from a few feet in length and width to mile-long masses that exceed 30 feet in thickness (Chenoweth, 1977), commonly parallel to paleostream channels. They are generally found in confined sandstone aquifers where ore deposition may be the result of aqueous transport of soluble uranyl carbonate species ($UO_2(CO_3)_2^{2-}$, $UO_2(CO_3)_3^{4}$). Where reducing conditions are encountered in the sandstone unit (Westwater Canyon), precipitation of uranium(IV) minerals occurs in a mineralized "front."

Principal uranium minerals found in the Ambrosia Lake mines include coffinite ($U(Si0_4)_{1-x}(OH)_{4x}$), carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_20$), tyuyamunite ($Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}8H_20$), and andersonite ($Na_2Ca(UO_2)(CO)_3 \cdot 6H_20$) (Longmire et al., 1984; Granger, 1968; Squyres, 1970). The mineralogy of the host rock consists of quartz, potassium, and sodium-rich feldspars, kaolinite, montmorillonite, illite, chlorite, mixed-layer clay minerals, hematite, magnetite, and pyrite (Kendall, 1971; Squyres, 1970). Uranium deposits are also enriched in a variety of other elements including arsenic, molybdenum, lead, selenium, thorium, manganese, iron, radium, zinc, chromium, cobalt, vanadium, barium, and strontium (Spirokis et al., 1981; Brookins, 1979).

1.4.3 Hydrogeology

Figure 1-6 is a schematic hydrogeologic cross section through the San Juan Basin. The principal hydrogeologic unit of concern to this Stage 1 investigation is the Westwater Canyon Member of the Morrison Formation, which extends throughout the San Juan Basin. In the Ambrosia Lake Valley, the thickness of the Westwater Canyon is generally between 80 and 180 feet and that of the Brushy Basin Member is 80 to 100 feet (Stone et al., 1983).

Locally, in the Ambrosia Lake Valley, the Mancos Shale contains three water-bearing sandstones—the Tres Hermanos A, B, and C—that are not present in the rest of the basin (Santos and Thaden, 1966). The Brushy Basin Member acts as an aquitard that separates the Westwater Canyon Member from the Dakota Sandstone, and the Mancos Shale acts as an aquitard separating the Dakota Sandstone from stratigraphically higher water-bearing units (Stone et al., 1983).

1.4.3.1 Ground Water Recharge

Areal recharge occurs only after near surface processes such as runoff, evaporation, transpiration, and sublimation have depleted any precipitation and some small residual amount of water is able to reach the saturated zone. Bedrock units receive recharge where they crop out and in higher-elevation areas where they subcrop beneath saturated alluvium (Stone et al., 1983). Recharge from streamflow losses to alluvium and subsequent downward flow from the alluvium to the bedrock units occurs mainly along the northern margin of the San Juan Basin where the larger streams draining the San Juan Mountains in Colorado flow across surface exposures of the more permeable bedrock units. Recharge from streamflow losses also occurs to a lesser extent along the upper reaches of the Rio Puerco, Rio Salado, and Puerco River.

Regional ground water flow patterns in the deeper aquifers are from the primary recharge areas on the flanks of the San Juan Basin toward the basin center and subsequently toward the principal locations of discharge: the lower San Juan River in the northwest corner of the basin and the Rio Puerco in the southeastern corner of the basin (Stone et al., 1983). A minor amount of discharge also occurs to the Puerco River in the southwestern corner of the basin. Discharge to streams generally occurs through the alluvium in the river valleys, but ground water also migrates from bedrock aquifers to alluvium, where it is lost through evapotranspiration. Regional ground water flow patterns in the shallower aquifers (above the Mancos Shale) in the interior of the basin follow a similar pattern, but are more strongly controlled by discharge to alluvium in the valleys of the Chaco River and its ephemeral tributaries.

Modeling of steady-state ground water flow in the Jurassic and younger rocks of the San Juan Basin by the United States Geological Survey (USGS) (Kernodle, 1996) indicates that flow through the regional aquifer system is approximately 195 cubic feet per second (cfs), which is about 1 percent of the average annual precipitation in the basin. Kernodle calculated the regional mass balance for the ground water flow system to include gains of 135 cfs from streambed infiltration, 56 cfs from direct precipitation, and 4 cfs from downward leakage from the Chuska Sandstone (which occurs only in the far western portion of the basin; see Figure 1-4). These computations indicated that all the water is discharged to the surface-water system, with the outflow being equal to the inflow.

1.4.3.2 Influence of Uranium Mining on Regional Ground Water System

Uranium was mined from the Westwater Canyon Sandstone over a wide area in the Ambrosia Lake Subdistrict. Figure 1-7 illustrates the extensive mine workings that were developed in the subdistrict, many of which are known to be interconnected. The Westwater Canyon, the overlying Dakota Sandstone, and local sandstone beds in the lower Mancos Shale were essentially dewatered in the vicinity of the mines by activities that began in the late 1950s and ended by 1986. A regional cone of depression formed within the bedrock units because of the presence of vent holes and mine shafts and the dewatering of the mines (Bostick, 1985).

Since 1986, water levels in these units have been recovering as ground water flows back into the dewatered areas from the surrounding area. Ground water removed from the mines was discharged to the Arroyo del Puerto drainage system and saturated portions of the formerly dry alluvium that fills the valley cut into the bedrock units. Some of that water re-entered the bedrock through downward seepage into underlying sandstone units, and some re-entered through mine shafts and vent holes penetrating the alluvium.

1.4.4 Geochemical Setting and Ground Water Quality

In the Ambrosia Lake Valley, where the primary ore-bearing unit is the Westwater Canyon Sandstone, some water quality data is available from areas adjacent to the mines. However, regional data to characterize ground water quality are sparse (see Section 3 for more discussion on regional water quality data). Although ground water from the Westwater Canyon Sandstone is used for industrial, agricultural, and domestic purposes in areas of the San Juan Basin, overall development of this ground water resource is limited, as are associated water quality data. In part, the lack of data about this aquifer is due to the depth of its occurrence in much of the basin (Longmire, 1983). Primary sources of available ground water quality data include the USGS (Dam, 1992; Kernodle, 1996), the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) (Stone et al., 1983), the NMED (Longmire et al., 1984; Goad et al., 1980; Gallaher and Cary, 1986; and Bostick, 1985), and others as discussed further in Section 3.

The behavior and transport characteristics of uranium, iron, and sulfur species are primary influences on ground water quality at Ambrosia Lake mines. Where reducing conditions are encountered in the sandstone unit (Westwater Canyon), precipitation of uranium(IV) minerals occurs in a mineralized "front" (see Map 3, McLemore and Chenoweth, 1991).

The process of mine dewatering may have introduced oxygen into previously reduced ore zones in the Westwater Canyon Sandstone causing uranium to be oxidized to the hexavalent (VI) state, forming a uranyl ion (UO_2^{2+}) in the process. Uranium is more soluble in oxidizing environments than in reducing environments. Ground water quality in mine voids is highly sensitive to small variations in the amounts of both pyrite and oxygen that are available for reaction. Both constituents have an effect on reduction-oxidation conditions. Therefore, small variations in these factors at or within a given mine may result in highly variable ground water quality.

3.0 Regional Ground Water Evaluation

3.1 Regional Ground Water Data

The Site lies in the Ambrosia Lake Subdistrict, a region of interconnected mine workings; therefore, the water quality evaluation includes comparisons of Site data to data from nearby locations. The purpose of this review is to provide a baseline database against which data collected from the Site can be compared. This is necessary to characterize ground water quality conditions at the Site, as required by the NMED.

Mining began in the Ambrosia Lake Subdistrict before the importance of establishing baseline conditions was recognized. Consequently, data that would help define the conditions that existed before the advent of mining activities are sparse. Further complicating the effort is the fact that the Westwater Canyon Member is a heterogeneous, ore-bearing aquifer, which exhibits significant variability in matrix composition and water quality, even across short distances. This variability makes it difficult to establish meaningful baseline values at a regional level.

That being said, as required by the approved Stage 1 Plan, INTERA developed a database of existing water level and water quality data in the region as a baseline for the comparison of Section 27 water level and quality data. This database, referred to as the Section 27 baseline database, contains regional information from published and unpublished sources, including the following:

- Department of Energy
- Nuclear Regulatory Commission
- New Mexico Environment Department
- Environmental Protection Agency
- United States Geological Survey
- New Mexico Bureau of Mines
- University theses on issues related to uranium mining and milling in New Mexico
- General scientific literature

As requested by UNC, INTERA performed a review of these sources to obtain ground water and surface water data for the Ambrosia Lake Valley area and developed the database described further in Section 3.2. The reference list provided in Section 5 includes all data sources used to develop the baseline database. The following discussion summarizes the main objectives and conclusions provided in some of the more significant data sources; this discussion highlights the complexity of the water chemistry in the Ambrosia Lake Valley area. The locations from which data were available are shown by township, range and section on Figure 3-1. Though the database has many entries, there are large areas of the Ambrosia Lake Subdistrict not represented, as can be seen in Figure 3-1. The following discussion provides a summary of some of the key data sources that went into the development of the Section 27 baseline database.

NMED provided INTERA with a database that contains a great deal of historical data for the Ambrosia Lake Valley. In addition to analytical data for ground water in mine shafts and vent holes from 1958 through 2005, the NMED database also contains information on water levels in the mine shafts and vents holes from 1987 through 2005. However, although the NMED database contains a large amount of data that covers a long time period, it is limited in other respects. For example, the database only has results for data that were reported as being above the detection limit, but it has no qualifying information on what the detection limits were. Even so, because of the large amount of data available for certain constituents, the database is useful for the analysis of trends over time.

In 1975, the Environmental Protection Agency (EPA) Region VI completed a study titled *Water Quality Impacts of Uranium Mining and Milling Activities in the Grants Mineral Belt, New Mexico*. This study had been requested by the New Mexico Environmental Improvement Agency (now NMED) in 1974 to assist in determining the impact of uranium mining and milling activities on surface water and ground water. The objectives of the study were to:

- Assess the impacts of waste discharges from uranium mining and milling on surface and ground water of the Grants Mineral Belt.
- Determine if discharges comply with all applicable regulations, standards, permits and licenses.
- Evaluate the adequacy of company water quality monitoring networks, self-monitoring data, analytical procedures and reporting requirements.
- Determine the composition of potable waters at uranium mines and mills.
- Develop priorities for subsequent monitoring and other follow-up studies.

A reconnaissance study was conducted in January 1975 to view the study areas, meet with the operators and company officials, and plan the data collection effort. Sample collection began in February 1975, and was completed in early March 1975. Laboratory analyses for trace metals, gross alpha, radium-226 analysis, and other radiological analyses were completed in July 1975. A subset of the data collected in 1975 was included in INTERA's Section 27 baseline database.

In 1979, Robert Brod, then a graduate student at the New Mexico Institute of Mining and Technology, submitted a master's thesis titled *Hydrogeology and Water Resources of the Ambrosia Lake-San Mateo Area, McKinley and Valencia Counties, New Mexico* (Brod, 1979). This master's thesis is an overview of the geology and hydrology of the study region, with an emphasis on the regional setting. The discussion of water resources encompasses the entire hydrogeologic setting, not just the Westwater Canyon Sandstone. The thesis does contain a comprehensive list of wells in the Ambrosia Lake-San Mateo area, including information on location, elevation, depth, construction, and water level. It also contains tabular information on ground water quality from the study area. Data pertaining to the Westwater Canyon was extracted and included in the baseline data discussed below.

The New Mexico Environmental Improvement Division (now NMED) published *Water Quality Data for Discharges from Uranium Mines and Mills in New Mexico* in July 1980. The report was prepared to present data on water quality obtained by NMED during routine sampling of uranium mines and mills. These data were collected over a three-year period from 1977 to 1979. Samples were taken from all New Mexico uranium mines known to be undergoing dewatering, including discharges from uranium recovery facilities and at all operating uranium mills. In addition, this report included data for samples collected from wells completed into ore bodies that were to be mined via in situ leaching. The data provided in this report fall into four categories: active mines, mines under development, baseline ground water samples, and mill samples (tailings ponds, sumps, tailings water, and tailings liquor decant ponds). INTERA extracted data on raw mine discharge water quality data and mine-water-feed for ion exchange facilities from this report and included these data in the Section 27 baseline database.

Another 1980 report was published as part of Memoir 38 by the NMBMMR (1980) and titled *Effects of Uranium Mining on Groundwater in Ambrosia Lake Area, New Mexico (Kelly et al., 1980)*. The report focuses on how mining had affected water levels in the Ambrosia Lake Valley. A brief discussion at the end of the report also indicates how mining had affected regional water quality. By comparing major ion chemistry in the Westwater Canyon and Dakota Formations, the authors concluded that drawdown had probably caused leakage from the Dakota Sandstone into the Westwater Canyon Sandstone. Because ground water in the Dakota typically has higher total dissolved solids (TDS) concentrations than the Westwater Canyon, this leakage has the potential to degrade ground water quality in the Westwater Canyon Sandstone.

In 1983, the NMBMMR published a report titled *Hydrogeology and Water Resources of the San Juan Basin, New Mexico* (Stone et al., 1983). This report provides a good general overview of the entire San Juan Basin, with information on vegetation, geology, land use and ownership, and water resources, both surface and ground water. The ground water discussion includes both alluvial aquifers and the deeper confined aquifers associated with the Westwater Canyon Member. The report also contains a large section on the volume of ground water produced by mining activities in the Ambrosia Lake Valley and other parts of the basin. The report is an excellent resource for information on the San Juan Basin and contains microfiche appendices with data pertaining to water quality in the area. Most of the data do not pertain to the Westwater Canyon Sandstone; those that do were entered into the Section 27 baseline database.

In 1984, Patrick Longmire (NMED), Bruce Thompson (University of New Mexico), and Douglas Brookins (University of New Mexico) published a report titled *Uranium Industry Impacts on*

Groundwater in New Mexico (Longmire et al., 1984) as part of NMBMMR Hydrologic Report 7. The purpose of this report was to evaluate the geochemical interactions that occur among acid and alkaline leach-tailings seepage, ground water, and the soil matrix. This report includes some mine water data that was included in the Section 27 baseline database.

In 1986, Mr. Bill Ganus, who was a Vice President of the Kerr-McGee Corporation at the time, completed a report titled *Hydrologic Assessment of Quivira Mining Company Operations Ambrosia Lake Area, New Mexico* as part of an internal company document (Ganus, 1986). The purpose of this study was to evaluate the effects of underground mine ventilation holes on ground water levels in the Ambrosia Lake area. As described by Ganus, ventilation holes constructed in the Ambrosia Lake Subdistrict are designed to drain bedrock aquifers overlying the Westwater Canyon Sandstone. Typically the vent holes are 5 feet in diameter and extend vertically from the ground surface into the mines. The vent holes were lined with steel casing, but were not cemented in place along the bedrock borehole length. Drainage was permitted to move down to the mine level where it was captured by the mine shafts. The report provides vent hole locations and pre-mining water levels as well as some water quality data for mine shafts and surface drainages. These data were included in the Section 27 baseline database.

In 1990, the Department of Energy (DOE) published a report titled *Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, NM* as part of the Uranium Mill Tailings Remedial Action Project. This report lays out the DOE's plan for remediation of the tailings pile and contains a large amount of background information on the mill tailings site. Appendix D of the DOE report contains a large amount of pertaining to local soils as well as some ground water data related to quality and flow direction. The ground water data pertaining to the Westwater Canyon Sandstone were entered into the Section 27 baseline database.

MWH prepared a technical memorandum (MWH, 2004) to address NMED and MMD concerns about potential water quality impacts resulting from Section 27 mining. The objective of this study was to provide additional information on ground water quality within the Westwater Canyon Member near the Site, historical water quality analyses of Section 27 Mine water, and comparisons of regional and historical water quality data to a grab ground water sample collected on May 17, 2004 by MWH from VH-3. Data sources and analytical data for the Westwater Canyon Member are provided in this memorandum. INTERA obtained copies of the referenced sources and included both the data that MWH compiled and some data from the references in the Section 27 baseline database. The MWH references included EPA (1975), Brod (1979), New Mexico Environmental Improvement Division (1980), Kelly et al. (1980), and DOE (1990), all of which have been discussed above.

The EPA produced a report in June 2004 titled *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*. Attachment 1 of this document focuses on water quality of the San Juan Basin. Though this document does not contain water quality data specific to the Site, it provides good information on the geology and hydrology of the area, which was incorporated into this report.

3.2 Construction of the Section 27 Baseline Database

3.2.1 Data Screening

The Section 27 baseline database was constructed by INTERA with sample data from historical records using the methods described below. The database was designed to include the following information: sample ID, analyte, collection date, collection time, result, qualifier, reporting limit, detection limit, units, method, analytical lab, lab sample ID, report data source of data and comments.

A statistical summary of the key constituents from the database is provided in Table 3-1.

A screening approach for the selection of historical data was developed to ensure that the Section 27 baseline database would contain a consistent and appropriate level of information. Figure 3-2 is a schematic flow diagram that shows the decision process used to extract applicable data from the sources discussed above.

As shown in Figure 3-2, the first step was to determine what type of sample the data represented. The literature reviewed included data from wells, mine shafts, tailings ponds, mine workings, streams, and other sample locations. The only data of concern for this study were those that represented (1) surface water, (2) ground water samples from wells in areas not impacted by seepage from tailings facilities, (3) samples of ground water from mine dewatering activities (hereafter referred to as mine water), and (4) water levels. Any sample data that represented tailings ponds, ion-exchange water, leak detection wells, and other types of altered sources were not entered into the database.

The next step was to group data by data type: surface water, ground water, or mine water. Data that represented stream sampling along drainages in the Ambrosia Lake Valley were classified as surface water. Data that came from a well was classified as ground water. Data that represented the sampling of ground water from a mine shaft or vent hole were classified as mine water. The ground water data were further divided into two categories: wells screened in the Westwater Canyon Member and all other wells.

The final criterion was whether or not the data contained specific location information. If so, the location information was entered either into a separate table or included as part of the sample identification (as was done for surface water samples). If no location information was available, the data were not entered into the database. Location information could be latitude and longitude; northing and easting; township, section, and range; or simply a description of where the sample was taken. Mine water was only included if it was from a location within the Grants Mineral Belt.

Table 3-1 Statistical Summary for Historical Ambrosia Lake Valley Mine Water Data

Analyte	Unit	Number of Samples	Mean	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Standard Deviation	Skewness
Arsenic	mg/L	47	0.02	0.00	0.03	0.00	0.00	0.27	0.00	0.01	0.05	4.50
Bicarbonate	mg/L	194	267.37	257.12	277.62	276.00	38.00	730.00	240.00	302.00	72.37	0.96
Calcium	mg/L	201	243.70	221.27	266.13	264.00	1.60	720.00	76.40	379.00	161.28	-0.08
Chloride	mg/L	535	105.59	94.97	116.22	44.00	0.10	603.00	12.00	170.00	125.08	1.42
Iron	mg/L	158	1.33	0.81	1.84	0.10	0.01	18.80	0.02	0.40	3.28	3.03
Magnesium	mg/L	192	87.45	78.12	96.78	90.90	0.10	410.00	27.30	130.00	65.53	0.83
Molybdenum	mg/L	369	0.92	0.81	1.03	0.50	0.00	8.80	0.25	1.32	1.05	2.61
pH	mg/L	166	7.94	7.87	8.02	8.00	6.45	9.37	7.69	8.30	0.51	-0.21
Radium 226+228	pCi/L	402	81.96	73.51	90.41	59.10	0.05	809.20	26.00	111.00	86.17	3.03
Selenium	mg/L	360	0.16	0.14	0.18	0.05	0.00	1.53	0.01	0.23	0.23	2.27
Sodium	mg/L	228	281.49	265.18	297.81	288.00	18.40	800.00	180.00	364.00	125.01	0.60
Sulfate	mg/L	904	1140.64	1105.50	1175.77	1170.00	5.80	3030.00	735.50	1601.75	538.28	-0.11
Total Dissolved Solids	mg/L	474	1982.47	1892.92	2072.03	1900.00	6.10	5220.00	1167.00	2840.00	992.25	0.15
U_3O_8	mg/L	199	9.78	8.73	10.84	7.80	0.12	39.30	5.00	11.75	7.52	1.63
Uranium	mg/L	1121	10.87	10.35	11.38	8.50	0.00	51.20	5.50	12.90	8.83	1.57

Notes:

Lower 95% Confidence Interval = The lower value around the mean where the "true" mean can be expected to be located with 95% certainty.
Lower Quartile = 25th percentile of the sample population
Mean = arithmetic mean
Median = 50th percentile of the sample population
mg/L = milligrams per liter
Minimum = minimum detected concentration
Maximum = maximum detected concentration
pCi/L = picocuries per liter
Skewness = Measure of skewness of the data distribution; indicates degree of asymmetry and direction of the skewness (values greater than 2 indicate significant skew, with negative values indicating left skew, positive values indicating right skew).
Upper 95% Confidence Interval = The upper value around the mean where the "true" mean can be expected to be located with 95% certainty.
Upper Quartile = 75th percentile of the sample population

3.2.2 Historical Data Qualifiers

Compiling a database from a literature review is problematic due to the reporting variability and the lack of information that can be used to evaluate reliability (e.g., sampling methods, laboratory methods, quality assurance methods, etc.). Historical reports usually contain only summary tables; full laboratory reports are rarely available. As a result, the data are often presented with little or no qualifying information. None of the historical reports reviewed while compiling this database contained information on sample collection times, reporting or detection limits, laboratory methods, laboratory identification, or laboratory report date. Some data did include the laboratory sample identification, but this information is meaningless unless the name of the laboratory is also provided.

One of the most difficult problems to deal with when compiling a database of historical values is how to deal with non-detections. In summary tables non-detections are usually shown as (1) being less than the detection limit, (2) an "ND" (non-detect), or (3) simply left blank. In cases where values were reported as less than a specific detection limit (e.g., Cd = <0.01 mg/L), the detection limit was entered into the Results column of the database and a "<" was entered into the Qualifier column. Likewise, in cases where an ND was reported, the detection limit (when available) was entered in the Results column and a "<" was entered into the Qualifier column. If a result was reported as ND and a detection limit was not available, the Results value was left blank. A blank in a summary table can have two possible meanings: the constituent was not detected or no analysis was performed for that constituent. Unless more qualifying information was included to determine what a blank actually represented, the Results value was left blank in the database.

A properly reported radiological constituent should always contain a data qualifier that indicates a probable range (e.g., Ra-226 = 46.5 ± 3.1 pCi/L). For these constituents, the first number was always entered into the Results column, and the qualifying number was always entered into the Qualifier column.

Most data included the day, month, and year the sample was collected; however, some included only month and year. In these cases, the day was entered as the first day of the month.

3.3 Statistical Evaluation

INTERA performed a series of statistical evaluations on Section 27 baseline data from the data sources described above. Statistical evaluations on these data were used to determine a potential range in historical ground water quality in the Westwater Canyon Member. It should be noted, however, that the actual range of historical ground water quality may be different because of limited data (both in quantity and location) and the extreme variability of the aquifer matrix and other geochemical conditions over short distances.

3.3.1 Statistical Methods

3.3.1.1 Database Consistency

In general, statistical analyses were performed on 14 key analytes: arsenic, bicarbonate, calcium chloride, iron, magnesium, molybdenum, pH, radium-226+228, selenium, sodium, sulfate, TDS, uranium, and U_3O_8. These parameters are key because they are either (1) a basic water quality parameter or (2) a constituent that is chemically associated with uranium deposits in New Mexico and that has a New Mexico Water Quality Control Commission (WQCC) standard. To facilitate meaningful statistical analysis certain steps were taken to make each data set internally consistent.

First, the database was screened for negative values. Negative values related to radiological analytes were retained because a negative result is possible with radiological analysis. In some cases a minus sign had been used to indicate a result was "less than" a minimum detection limit. In this case, the minus sign was removed and the result was retained as described in Section 3.2.2.

Per EPA (1989) guidance, all results indicated as non-detections were replaced by a value that was one-half of the reported detection, reporting, or practical quantitation limits to prevent the data set from being censored on the low end. Since the value could be anywhere between zero and the detection limit, this substitution allows a 50 percent probability that the substituted value will be higher or lower than the real value, provided that the distribution is normal.

3.3.1.2 Summary Statistics

For the purpose of this analysis, a data set is defined as all of the analysis results for a single constituent across the entire Ambrosia Lake Valley. Summary statistics for each data set are presented in Appendix E.

Descriptive summary statistics and information presented in Appendix E include the following:

- Chemical name of constituent
- Geologic unit
- Number of samples
- Arithmetic mean
- Geometric mean (the back-transformed mean of the log-transformed data)
- Standard deviation
- Arithmetic mean plus two standard deviations
- 95 percent upper confidence limit on the arithmetic mean (likely upper value of the arithmetic mean)

- Minimum reported concentration
- Maximum reported concentration
- 25th percentile of sample population
- Median
- 75th percentile of sample population
- Interquartile range (range between the 25th and 75th percentiles)
- Shapiro-Wilk W-value for untransformed data
- Shapiro-Wilk p-value for untransformed data, where a p-value less than 0.0500 indicates sample population is not normally distributed (nonparametric or lognormal distribution)
- Shapiro-Wilk W-value for log-transformed data
- Shapiro-Wilk p-value for log transformed data, where a p-value less than 0.0500 indicates the sample population is not lognormally distributed (nonparametric or normal distribution)
- Distribution of sample population; either normal, lognormal, or nonparametric, based on results of the Shapiro-Wilk test

Statistical analysis also included the following:

- Box-and-whisker plots were used to determine whether outliers or extremes were present in the data set.
- Distributional testing was used to confirm that data fit a normal distribution using histograms, normal probability plots, and the Shapiro-Wilk W-test; if data were not normally distributed, the data set was log-transformed and tested again.

3.3.1.3 Box-and-Whisker Plots

Box-and-whisker plots (Appendix F) were constructed using STATISTICA data analysis software (version 7.1, Statsoft Inc., 2005) as part of the data evaluation for this investigation. These plots are used to describe and compare data distributions and to highlight disparate results known as extreme values. The height of the box represents the 25th lower boundary value and 75th upper boundary value percentile range of the data set; the median value is plotted within this box. The whiskers represent the range within which 5 to 95 percent of all values fall. A default outlier coefficient of 1.5 was selected for this analysis; thus, an outlier was a data point that fell at least 1.5 times the height of the box above or below the whiskers. Extreme values were identified as outliers that were more than 3 times the height of the box above or below the whiskers.

An extreme is an observation that does not conform to the pattern established for other observations. Such values may be mistakes such as transcription or reporting errors, or may be the result of instrument or laboratory errors. Extremes may also represent inherent variability in the measured parameter. Extremes that are found to be mistakes should be corrected or described and excluded from calculations.

A number of values taken from the MWH technical memorandum (MWH, 2004) were initially shown as extremes. However, it was found that there was an error in recording the units. The original source of the data, the USGS, reported values in µg/L; however, MWH recorded the values as mg/L, creating an error of three orders of magnitude in the reported concentrations. These data were corrected in the database and the analyses were rerun. In cases where the extreme could not be verified as an error, summary statistics and tests were performed both with and without the extreme. Once identified, extreme values were flagged in the original data set. A new data set was created omitting the extremes. Because the exercise of identifying extremes is somewhat circular, with a new set of extremes appearing every time the old ones are eliminated from the data set, a decision rule was applied to limit potential abuse. The first pass of identifying and eliminating extremes was used as a limiting control on this technique. Any subsequent extremes that were identified were retained for analysis unless eliminated for another reason.

3.3.1.4 Distributional Testing

Most statistical tests assume that data represent a normal distribution. EPA guidance (1992) suggests that a lognormal distribution is a more appropriate default statistical model for most ground water data; however, even this assumption commonly fails, requiring the use of nonparametric methods. Parametric statistical methods are preferred due to higher statistical power, but nonparametric methods should be used when normality or lognormality cannot be verified. It is important to identify the distribution of the data because data that do not fit assumptions made in designing statistical operations can lead to false conclusions.

Histograms were generated for each constituent in each well (Appendix G) and the Shapiro-Wilk test (Shapiro and Wilk, 1965) was applied for population distribution. The histograms were generated using untransformed data and log-transformed data. For the Shapiro-Wilk test to have sufficient power to reject the hypothesis of normality (or lognormality), the sample number, or "n" should be at least 20. Results of the Shapiro-Wilk test and designation of distributional type are provided in the table of summary statistics for each constituent in each well (Appendix E).

Normal probability plots are also useful for visual identification of outliers and to evaluate the possible presence of multiple populations within a data set. A probability plot consists of a graph of values, ordered from lowest to highest and plotted against a standard normal distribution function. Populations of data that plot as a straight line in a linear scale are referred to as normally distributed, and populations that plot as a straight line in a logarithmic scale are referred to as lognormally distributed.

Probability plots for the baseline data (Appendix H) show the concentration of a chemical in each sample in a manner that also indicates how well the data set for the chemical fits a normal or lognormal distribution. The concentrations of some naturally occurring chemicals follow a lognormal distribution, so the original data were also log-transformed and then plotted to qualitatively assess the fit to a lognormal distribution (distributional tests such as the Shapiro-Wilk test provide a quantitative measure of how well the data fit a particular distribution).

3.3.1.5 Trends in Concentration

Temporal trends in data were evaluated graphically using time-concentration plots (Appendix I) and the Kendall tau test (Appendix E). Although extreme values were excluded from the trend analysis, additional outliers that were not obvious on the box-and-whisker plots are apparent in normal probability plots and should be evaluated further and possibly excluded in subsequent evaluations.

The Kendall tau is a nonparametric test that provides a probability indicating whether the arrangement of data over time represent a temporal trend or is due to chance (random). The Kendall tau test was applied for constituents with at least eight samples. A summary of the significant results from the Kendall tau test is presented in Appendix E. The 95 percent probability level (i.e., p-values less than or equal to 0.0500) was set as the statistical indicator of a temporal trend.

3.3.2 Regional Baseline Database Discussion

Regional data to characterize ground water quality are sparse in the Ambrosia Lake Subdistrict. The Section 27 baseline database serves as an approximation of a potential baseline to ground water in the mine voids at the Site because it represents ambient ground water quality in the interconnected ground water system across Ambrosia Lake Valley. However, these data are of unknown quality and the original data records and qualifiers are lacking. Little to no information is available that indicates which part of the water column is represented by the water quality data. In fact, these data could possibly represent sampling locations as diverse as the top of the water column, any location within the water column, or a sample of pumped mine water discharged to the arroyo. Also, there are no data on other specific factors in these mines such as position of the sample relative to stratigraphy, mineralogy, ore deposits, vent hole casing, or stage of ground water recovery, all of which could affect the quality of water measured in a sample.

Box-and-whisker plots are useful to describe and compare distributions of constituents from different mine shafts and other available data for the Westwater Canyon Sandstone. The box-and-whisker plots shown in Appendix F highlight the broad variability of constituent concentrations in the Westwater Canyon. For comparison, the Section 27 data distribution is shown in a shaded area on all of the box-and-whisker plots.

Appendix F shows that the measured concentrations of arsenic at all of the mines are below the WQCC limit of 0.1 mg/L, except for two extreme values. However, the baseline data sets for chloride, iron, molybdenum, radium-226+228, selenium, sulfate, TDS, and uranium contain measured values that are above the respective WQCC limit.

Appendix H contains the probability plots for the baseline data. Though there is some variability, these plots, as well as the Appendix G histograms, reveal a significant level of normally distributed data.

Temporal plots for key parameters are provided in Appendix I for the baseline data sets. Concentrations for indicator parameters such as sulfate, TDS, uranium, and radium-226 have dropped at some locations, as might be expected in stopes that have already been flooded, and conditions are returning to their pre-mining state. Exceptions to these general trends can be observed in time-concentration plots of ground water data from mines along the axis of the ground water cone of depression (i.e., the 30 West, 33, 35, and 36 mines) (Figure 2-1). These mines, which were among the last to discontinue mine dewatering, exhibit rising-to-flat trends in sulfate and TDS concentrations. However, there are indications in some of the mines that concentrations have reached a maximum (e.g., in the 30 West and the Section 30 mines), and may be beginning to decline. Also, the hydrographs shown in the Appendix I figures indicate rising ground water elevations over time. In general, as water levels go up regionally, water quality improves.

Figure 3-3 provides modified stiff diagrams using the most recent values of selected constituents from the NMED mine shaft data set. Constituents were selected for the stiff diagrams based on primary constituents of concern in mine shafts and data availability. The diagrams provide another type of visual record of the variability in ground water quality data across Ambrosia Lake Valley as well as the variability of water quality at a given location. For example, the Section 23 mine has relatively low sulfate and TDS but also exhibits the highest observed concentrations of molybdenum. This distribution of molybdenum is likely related to the abundance of molybdenum in the Section 24 ore deposits.

Many of the mine shafts that show the highest average TDS values on Figure 3-3 are located along the ground water cone of depression (Figure 2-1). The observation that this area includes the only mines with increasing concentrations of constituents in ground water as well as the highest average TDS concentrations suggests that the geochemical system in the cone of depression is currently the most active in the area. The poorer water quality and lack of improving trends in this area likely indicate that these areas are currently the most chemically active because they are the locus of the oxygen-ground-water front within the ore materials. Water provides the medium that allows reactions to take place. As water rises through the stopes, the surface (air-water interface) is the location of the most abundant oxygen for reaction. Water below the air-oxygen interface has been depleted in oxygen and ore material above the interface is dry.

Note that the mine stopes themselves form a complex three-dimensional system of subsurface voids. The stopes partly correspond to the original distribution of uranium ore, but are not completely coincident with all uranium mineralization because of mine construction (e.g., they need to be interconnected from level to level and from the surface), because exploration may not be complete, or because mineral deposits may not be economic to produce. Therefore, it is difficult to pinpoint the exact location of the air-water interface that may be influencing ground water quality measured in samples from a particular shaft or vent hole.

It is possible, however, to discern broad trends that control the air-water interface and therefore influence ground water quality in the mine stopes. In general, the Westwater Canyon mineral belt in the Ambrosia Lake Subdistrict is oriented from northwest to southeast and dips to the northeast. As a result, the mines get progressively deeper to the southeast. In addition, faulting has displaced the Westwater Canyon to deeper levels of the subsurface on the southeast portion of the Ambrosia Lake Subdistrict. Therefore, ground water will return to the Westwater Canyon in the eastern portion of the district first, and mine stopes in the vicinity of Sections 34, 35 and 36 will be flooded long before the stopes in the vicinity of Homestake Sapin Mine or Kermac Mine no. 22 on the far northwest end of the district are flooded. As the cone of depression recovers, mines in the eastern area will be flooded and reach equilibrium conditions before those in the west, and geochemical conditions will change over time as repressurization moves from east to west across the district. This limits any capability to predict ground water quality at any particular time or place.

The final equilibrium ground water quality in the Westwater Canyon will depend, among other things, on the volume and availability of reactive minerals that are present in the aquifer matrix. The distribution of these minerals is not homogeneous across the Grants Uranium District. Although some parts of the Westwater Canyon host rock were rich in uranium and a number of associated reactive minerals, other sections are barren, with smaller volumes of reactive minerals. Thus, the composition of the aquifer matrix is highly variable across the district, a factor which makes it difficult to define the background or baseline value against which Section 27 data can be compared. Further discussion of this issue is provided in Section 4.

The baseline water level data supports the observation that ground water in the Ambrosia Lake Valley is flowing toward the cone of depression that resulted from dewatering of uranium mines (Figures 2-1 through 2-5). Hydrographs (Appendix I) indicate that water levels are rising in all mine shafts in the region.

4.0 Ground Water Quality Impact Analysis

4.1 Factors Affecting the Concentration of Uranium in Ground Water

A major focus of this Stage 1 investigation was to provide data that will help characterize the hydrogeology and water quality at the Section 27 Mine and, if necessary, help define an effective abatement strategy. The results of the field investigation, presented in Section 2, provide a snapshot of the current Site conditions. However, because active mining was initiated in the Grants Uranium District before the promulgation of EPA and WQCC regulations pertaining to uranium and other constituents, there is a lack of pre-mining water quality data from the ore-bearing formations that would effectively establish background conditions against which mining impacts can be measured. Given the complexities discussed in this report, and this lack of pre-mining data, the water quality from Section 27 vent holes must be evaluated together with the regional water quality data to assess the potential level of impact associated with mining at this site.

Uranium is a naturally occurring radioactive element and heavy metal in ground water. In December 2003, the EPA began regulating uranium in community water supplies with the goal of reducing the risk of cancer and kidney disease (Sherman et al., 2007). In 2005, the WQCC for uranium was reduced from 5,000 µg/L to 30 µg/L, which is equivalent to the EPA maximum concentration level (MCL). Uranium occurs naturally at concentrations higher than 30 µg/L even in areas that have not experienced uranium mining.

Elevated uranium in ground water has been reported in numerous regions of the U.S. As part of a national study, Focazio et al. (2006) found that uranium exceeded the MCL of 30 µg/L in approximately 4 percent of the 2,390 wells evaluated. Case studies have qualitatively shown that elevated uranium concentrations occur in oxidized ground water associated with uranium-rich deposits (Sherman et al., 2007). While ground water concentrations are highly sensitive to geochemical and host rock parameters, they are also influenced by residence time, which adds an even greater degree of complexity to an already complex problem. There is a recognized need in the scientific community for a better quantitative understanding of the geochemical and host rock parameters that result in elevated uranium occurrences.

In an attempt to shed some light on the complexity of the distribution of uranium in the Jacobsville Sandstone aquifer in Michigan's Upper Peninsula, Sherman et al. (2007) evaluated the spatial variability of ground water uranium concentrations in relation to geochemical conditions, the heterogeneous distribution of uranium in the host rock, and the increase in ground water age along flowpaths. Though this region has had a history of uranium prospecting, no economical deposits have been located, thus impacts from mining are not relevant in this study area. Documented ground water concentrations of uranium in this region range from below the detection limit to 224 µg/L. Some conclusions reached by Sherman et al. that are pertinent to the Section 27 water quality evaluation include the following:

- Regions with high Eh and elevated uranium in the bedrock are at risk for elevated uranium in ground water at a formation or district scale.
- Within a given region, there may be significant spatial variation in ground·water uranium concentrations, with elevated anomalies typically occurring in groups.
- The spatial variability of uranium in ground water does not always correlate to spatial distribution of uranium in the aquifer materials.
- Twenty-nine percent of the 218 wells located in the Jacobsville Sandstone aquifers produced water samples with uranium concentrations above the applicable MCL.
- Natural uranium enrichment in the Jacobsville Sandstone aquifer increases the likelihood that wells in its oxidized aquifers will have uranium concentrations above the MCL.
- By itself, the uranium concentration of the host rock in the vicinity of the well is not enough to predict if a well will produce uranium above the MCL. This indicates that there are other hydrogeochemical factors, such as the age of ground water, which may influence the effects of the uranium enrichment in the sandstone.

4.2 Regional Water Quality Issues for Grants Mineral Belt Ore Deposits

It is important to understand the scale of the various factors that influence the water quality of ground water in the mine stopes in the Ambrosia Lake Subdistrict. As has been discussed above, the mines of the Ambrosia Valley Subdistrict occur within the larger Grants Uranium District. Many underground mines exist in various stages of reclamation and restoration along the Grants Mineral Belt and at least 12 underground mines form an interconnected system of mine voids in the subsurface beneath the Ambrosia Lake Subdistrict.

Ore deposits in this area occur from the land surface in the far northwest part of the valley to depths of at least 2,500 feet bgs in the Section 36 Mine in the southeast portion of the valley (Figure 1-1). The deposits are irregular in shape and range from a few feet in length and thickness to mile-long masses that are over 30 feet thick (Chenoweth, 1977). The deposits commonly form parallel to paleostream channels. The deposits formed in the Westwater Canyon Sandstone, which is typically composed of alternating, lense-like sandstone and mudstone interbeds. The scale of interbedding ranges from inches to a few tens of feet. Ore deposits within this stratigraphic section may exist at multiple levels at any one location with unmineralized lenses of Westwater Canyon Sandstone above and below. Figures 4-1 and 4-2 illustrate these concepts. Figure 4-1 shows the irregular shape of these deposits and Figure 4-2 illustrates the vertical variability of the deposits. It is common to transition from uranium ore to uneconomic waste rock in a distance of inches.

The quality of ground water at any particular location is primarily a function of three factors: (1) the composition of the aquifer matrix that ground water has encountered, (2) pH, and (3) Eh.

Both pH and Eh can be affected by a number of variables, including the level of dissolved oxygen. In general, however, these three primary factors influence the behavior and transport characteristics of uranium, iron, and sulfur species, which, in turn, are primary components driving variability in ground water quality at Ambrosia Lake Subdistrict mines.

When uranium-rich solutions encounter reducing conditions in a sandstone unit, precipitation of uranium(IV) minerals occurs in a mineralized "front." Ground water quality in mine voids is highly sensitive to small variations in the amounts of both pyrite and oxygen that are available for reaction. Both constituents have an effect on oxidation-reduction conditions. Pyrite is present in amounts ranging from zero up to 2 percent of the ore zone (Longmire et al., 1984) and is variable on the scale of feet or, possibly, inches in an ore zone. The presence or absence of oxygen is dependent on the extent to which ground water has been in contact with air and isolated from reducing agents.

Underground mining may have disturbed ground water within the uranium front at Ambrosia Lake Valley. The process of mine dewatering may have introduced oxygen into previously reduced ore zones in the Westwater Canyon Sandstone causing uranium to be oxidized to the (VI) state and forming a uranyl ion (UO_2^{2+}) in the process. Uranium is more soluble in oxidizing environments than in reducing environments.

Before mining began, uranium ore zones were isolated from air and therefore lacked oxygen. As the Morrison Formation was dewatered to allow uranium mining, ore zones were exposed to oxygen and the following pyrite oxidation half-reaction could occur:

$$FeS_2\text{ (Pyrite)} + 8H_2O = Fe^{2+} + 2SO_4^{2-} + 16H^+ + 14e^-$$

This equation, together with the accompanying half-reaction whereby oxygen is reduced to water, yields the following:

$$FeS2 + {}^7/_2O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$$

The net result of pyrite oxidation is production of sulfate ions and acid (H^+). The production of sulfate ions increases the TDS concentrations in ground water within the stopes, and increased acidity leads to increased concentrations of dissolved metals.

However, when mine stopes are flooded, oxygen will be consumed and, if there are no other sources of oxygen, conditions will become more reducing. This favors the removal of Eh-sensitive constituents from ground water. Note that reducing conditions will likely migrate from southeast to northwest across the Ambrosia Lake Valley as mine stopes fill with water. The shape of the cone of depression, its duration, and the slow velocity of ground water flow suggest that flow toward the mine area should occur for a significant period of time (Bostick, 1985). Ground water flow and the geochemical processes described above indicate that any water quality changes that may have resulted from numerous operators conducting underground mining and stope dewatering will be contained within the Grants Mineral Belt and abated to a likely pre-mining state over the next 200 to 400 years.

4.3 Comparison of Section 27 Data to Regional Baseline Data

A comparison of ground water quality data from the Section 27 Mine and other locations in the Ambrosia Lake Subdistrict will help to (1) determine whether or not the Section 27 data coincides with regional data, (2) ascertain the probable reason for any discrepancies—including the impact of mining activities and possible bias in previous sampling methods, and (3) provide a basis for possible recommendations regarding remedial actions of Site 27 ground water.

As discussed previously, the three vent holes in Section 27 are aligned and parallel to an isopleth in the potentiometric surface developed from the regional baseline data (Figure 2-1). Therefore, as expected, the difference in water level elevations between the three vent holes is small and is expressed in tenths of a foot. As illustrated in Figure 2-1, ground water flow from Section 27 is currently to the south toward the regional cone of depression.

The complex and interrelated flow history of the ground water in this region indicates that the ground water in the Section 27 Mine shafts and vents conceivably originated from multiple sources including several mines and two mill/tailings facilities. Thus, current water quality is potentially a composite of several possible sources.

Section 27 Mine data (represented by the shaded portion of the graphs in Appendix F) typically falls within the range of baseline data. In the case of arsenic, the Section 27 Mine has the broadest range of concentrations of any of the regional mines, although all values remain below the WQCC. The only constituents measured in Section 27 ground water that are above human health standards are radium-226+228 and uranium. However, radium-226+228 and uranium concentrations measured in samples of Section 27 ground water are well within the demonstrated range of baseline data values. Sulfate and TDS concentrations measured in Section 27 ground water are above aesthetic standards for domestic water supplies. While box-and-whisker plots provided in Appendix F indicate that Section 27 analytical values for sulfate and TDS are above median values in the baseline data, they are well within the overall range of baseline values.

Iron and manganese concentrations measured in Section 27 ground water are also above aesthetic standards for domestic water supplies. While there was no baseline manganese data for comparison, the Section 27 iron values (26.9 to 45.8 mg/L) are an order of magnitude above the median baseline data value and the New Mexico standard for this constituent (1.0 mg/L). Iron values are also an order of magnitude above the theoretical solubility of iron in ground water (Hem, 1992) at the pH values observed in Section 27 ground water (6.8 to 7.4), suggesting either sampling or laboratory difficulties. Laboratory analytical reports (Appendix D) indicate that samples with unusually high iron concentrations also display unusually high concentrations of total suspended solids (TSS) (44-102 mg/L), in spite of having been filtered through a 0.045 micron filter in the field; this suggests that iron is present as colloidal solids rather than dissolved in solution. These solids may be the result of corrosion of iron vent hole casing materials that were disturbed by sampling activities. In any case, these extremely high concentrations of iron are unlikely to represent conditions in mine stopes.

As explained in Section 3, the Ambrosia Lake Subdistrict baseline data obtained from NMED is of unknown quality; also, it is unclear whether these data were collected from the top of the water column or from grab samples of pumped mine water. Vent hole profiling conducted by INTERA, both for UNC and for other clients in the Grants Uranium Belt, provides evidence that ground water quality in the Westwater Canyon Sandstone varies vertically as well as horizontally; therefore, a sample from the top of the water column is unlikely to be representative of water quality throughout a mine shaft or stope.

Additionally, vent hole profiling using probes to measure conductivity, pH, temperature, ORP and DO provide data on changes to water quality with depth at the Site. Figures 2-6 through 2-20 provide profiles for each probe-measured parameter. These figures also include the depths at which laboratory samples were collected as well as laboratory-measured values for uranium, radium-226, and gross alpha. Note that the shallowest sample in each vent hole was taken 15 to 20 feet bws, not at the top of the water column. Profiles of VH-1 exhibit vertical stratification of water quality with a marked discontinuity at about 30 feet below the top of the water column. Temperature data values increase from 68.9° F to 69.6° F. At the same depth, the conductivity increases from 4,280 µS/cm to 4,523 µS/cm. pH values decrease from near 7.5 to less than 6.9 with increasing depth, and ORP values increase with depth. Radiological values are much higher in the deeper zone sample from VH-1.

The stratification of the water column measurements in VH-1 indicates that the vertical location of a sample from a vent hole water column is important to the resulting measurement. Section 3 discusses several possible sources of variability in ground water quality in the Ambrosia Lake Subdistrict mine workings. Even under straightforward conditions, it would be difficult to determine the exact causes of the vertical water quality variability in Section 27 vent holes. For example, to assess the influence of a given geologic unit on water quality it would be necessary to define the geology at each location with much more precision than is currently available—a few feet one way or another could make a considerable difference. Further, because the presence or absence of small amounts of pyrite in the aquifer matrix can make a large impact on water quality, it would be necessary to understand the mineralogy of each hydrogeologic unit with a high degree of certainty.

Because access to the mine workings is limited, and rock falls and the collapse of mine workings are likely to have occurred in the nearly 20 years since the mine was closed, it is difficult to know the current shape of mine voids. Without this knowledge, it is uncertain how much oxygen is available for interaction. Other factors also come into play. For example, it is necessary to assess the influence of the steel casing that protects the vent holes from collapse, as steel casings will corrode and could have an effect on water quality.

Even if these variables could be sorted out, three vent holes would not provide the kind of sampling density necessary to characterize multiple variables, each of whose distribution varies independently on a scale of feet. In fact, it is unlikely that the vent hole profiling and associated sampling for chemical analyses in the Section 27 Mine captures the full range of vertical variation in ground water quality, although it is almost certainly more complete than the baseline data sets.

The concept of water quality variability is further illustrated by Figures 4-1 and 4-2. Figure 4-1 is a map of the three Westwater Canyon Sandstone ore zones in the Ambrosia Lake Subdistrict; Figure 4-2 presents a schematic of representative drill holes across the zones. As described above, the data to determine the relationship between stacked ore (or other stratigraphic variables) and VH-1 profiles do not exist, but Figure 4-2 indicates that the top of the deepest ore horizon in the northern ore trend (Zone 3) is approximately 220 feet below the bottom of the Brushy Basin and approximately 160 feet below the bottom of the first ore horizon. It is clear that 90 feet of profiling does not account for the full vertical variability in water quality in VH-1 because, based on this analysis, not all ore deposits have been profiled.

Even though it seems likely that many of the baseline data were obtained from samples taken from the top of water column, and thus represent less-than-full vertical variability, the modified stiff diagrams in Figure 3-3 show broad horizontal spatial variability in the baseline data. In several cases, the baseline data, which represent the quality of ground water in the interconnected mine workings in Ambrosia Lake Subdistrict, are above the applicable WQCC standards.

4.4 Conclusions

This Stage 1 investigation and analysis has revealed the following conclusions:

- The Section 27 Mine lies within the Ambrosia Lake Subdistrict of the Grants Uranium Mining District. The ore deposits within the Westwater Canyon Sandstone are the source of ground water quality degradation in the area.
- The geochemistry of uranium in roll-front deposits is complex and results in ground water quality that varies greatly over space and time.
- The only constituents measured in Section 27 Mine ground water that are above human health standards are radium-226+228 and uranium, and these values are within the range of the baseline data set.
- Iron, manganese, sulfate, and TDS concentrations measured in samples of Section 27 Mine ground water are above the aesthetic standards for domestic water supplies. Section 27 Mine values for iron are also above the range of baseline data values.

However, it is likely that the high iron concentrations are due to sampling difficulties and/or laboratory error.

- Containment measures such as pump-and-treat remedies would not be effective at the Site for several reasons. First, they may change the pattern of ground water flow, which currently contains poor-quality ground water. As noted above, repressurization is occurring regionally, resulting in improved ground water quality and a return to pre-mining geochemical conditions in the Westwater Canyon Sandstone. Second, they would likely increase oxygen in mineralized areas, which would further degrade ground water quality. Finally, containment at the Section 27 Mine would not be feasible, given that the mine workings in the Ambrosia Lake Subdistrict are interconnected and ground water within the stopes can flow freely from one mine to another. Any attempt at containment would have to be regional, conducted at numerous mine sites simultaneously.
- Ground water quality in the Ambrosia Lake Subdistrict will improve in the long term through natural attenuation. This will occur throughout the region as the water levels recover from mine dewatering activities and oxygen is excluded from mine stopes, and will continue as the cone of depression in the Westwater Canyon Sandstone recovers over the next several hundred years.
- Until the cone of depression recovers, the ground water gradient will be toward the mine stopes, resulting in capture and sequestration of constituents of concern.

4.5 Recommendations

This Stage 1 Report meets the requirements of 20.6.2.4106 NMAC. As has been demonstrated by this investigation. the Section 27 Mine cannot be viewed as the source of a release of contaminants that can be removed or stabilized, any more than can any Ambrosia Lake Subdistrict mine where dewatering took place. In fact, there was no release; rather, the process of dewatering the basin allowed for the introduction of oxygen, which reacted with native materials. Also, it appears likely that natural attenuation mechanisms will result in the containment of the regional mining impacts.

In accordance with current regulations, there are several possible pathways forward for this Site:

- *A demonstration that water quality at the site is below an established background level and/or below the WQCC standards*

  The only constituents measured in Section 27 Mine ground water that are above human health standards are radium-226+228 and uranium. As discussed above, the Section 27 values for these constituents are within the range of the regional baseline values. Additionally, it is reasonable to expect that two of the three constituents that exceed baseline values but do not exceed human health-based standards (sulfate and TDS) would fall within the range of true baseline values if the available data were not so limited. There is no baseline data for manganese, and thus no way of knowing if the Section 27 concentrations of this constituent exceed baseline values. Iron appears to be the sole constituent that actually exceeds the range of baseline values, and this result may be due to sampling difficulties and/or laboratory error.

- *A demonstration of technical infeasibility and approval of an alternate abatement standard or granting of a variance for the remaining constituents.*

  To the extent that some constituents cannot be demonstrated to be below background levels and/or the WQCC standards, a demonstration of technical infeasibility may be made. Based on the basic principles of uranium geochemistry and hydrology and an understanding of the Ambrosia Lake Subdistrict, it is clear that pump-and-treat technology is not a feasible remediation strategy for this Site, nor are there other proven or innovative technologies that are applicable at this scale. Preliminary examination of any pump-and-treat option suggests that, upon reinjection, treated water would redissolve constituents that had been removed. Thus, water in the stopes would be no better than it was before treatment.

  The complexities and interrelatedness of the regional ground water system in the Ambrosia Lake Subdistrict make it difficult to develop a path forward for closure of the ground water abatement process at the Section 27 Mine. Local containment through pump-and-treat technology at the Section 27 Mine is not feasible because of the interconnected nature of the mine workings in the Ambrosia Lake Subdistrict. Any attempt at containment would have to be a regional effort; however, such an approach would impact the natural repressurization and improvement in water quality that has been occurring in the region since the cessation of mine dewatering. Given the limitations on the use of technical infeasibility in 20.6.2.4103E(2), it may be that a determination on technical infeasibility needs to be made as part of a petition for approval of an alternate abatement standard or a request for variance.

In an effort to develop a viable approach that integrates on-site realities with regulatory requirements, we recommend that discussions be opened with NMED concerning the path forward. Future activities could include monitoring or other activities at the Section 27 Mine as part of a regional effort to evaluate the recovery of regional water levels and subsequent improvement in regional water quality.

Table 2-3 Laboratory Results for Vent Hole Sampling

Analyte	NMWQCC Standard	VH-1 Depth Below Water Surface			VH-3 Depth Below Water Surface	
		15 feet	30 feet	85 feet	20 feet	80 feet
Anion/Cation Balance (±5) (%)	-	-1.60	-0.370	-1.65	-1.02	-2.84
Alkalinity, Total as $CaCO_3$ (mg/L)	-	148	142	412	338	340
Aluminum (mg/L)	5	<0.1	<0.1	<0.1	<0.1	<0.1
Anions (meq/L)	-	57.6	57.4	64.2	47.2	47.1
Arsenic (mg/L)	0.1	<0.001	<0.001	0.005	0.011	0.015
Barium(mg/L)	1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron (mg/L)	0.75	<0.1	<0.1	<0.1	0.2	0.2
Cadmium (mg/L)	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium (mg/L)	-	351	358	473	368	363
Cations (meq/L)	-	55.8	56.9	62.1	46.2	44.5
Chloride (mg/L)	250	39	41	42	21	21
Chromium (mg/L)	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Conductivity (μmhos/cm)	-	4750	4800	5080	3920	3900
Fluoride (mg/L)	1.6	0.2	0.2	0.5	0.4	0.4
Gross Alpha (pCi/L)	-	247 ± 6.1	247 ± 6.1	9570 ± 34.7	3020 ± 22.0	2960 ± 22.0
Iron (mg/L)	1	**43.7**	**45.8**	**41.4**	**26.9**	**28.2**
Lead (mg/L)	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium (mg/L)	-	89.7	89.5	79.5	46.0	44.6
Manganese	0.2	**3.96**	**3.94**	**6.27**	**3.4**	**3.39**
Mercury (mg/L)	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum (mg/L)	1	0.1	0.1	1.0	0.5	0.5
Nitrogen, Nitrate+Nitrite as N (mg/L)	10	<0.1	<0.1	<0.1	<0.1	<0.1
pH	-	6.71	6.7	6.65	7.06	7.03
Potassium (mg/L)	-	14.1	14.1	14.3	14.7	14.4
Radium 226 (pCi/L)	30	20.9 ± 1.6	22.4 ± 1.6	**42.0 ± 2.2**	**46.5 ± 3.1**	26.9 ± 1.8
Radium 228 (pCi/L)	-	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium (mg/L)	0.05	0.002	0.001	<0.001	0.001	<0.001
Silver (mg/L)	0.05	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium (mg/L)	-	660	676	681	517	486
Sulfate (mg/L)	600	**2570**	**2560**	**2630**	**1910**	**1910**
TDS Balance (0.80-1.20) (decimal %)	-	1.03	1.00	1.02	1.00	1.01
TDS (mg/L)	1000	**3930**	**3840**	**4250**	**3090**	**3090**
TDS Calculated (mg/L)	-	3820	3830	4180	3100	3060
Total Suspended Solids (mg/L)	-	102	98.0	70.0	58.0	44.0
Uranium (mg/L)	0.03	**0.592**	**0.594**	**24.5**	**8.50**	**8.44**
Vanadium (mg/L)	-	<0.1	<0.1	<0.1	<0.1	<0.1

Notes:

$CaCO_3$ = calcium carbonate
meq/L = milliequivalents per liter
mg/L = milligrams per liter
N = nitrogen
NMWQCC = New Mexico Water Quality Control Commission
pCi/L = picocuries per liter
TDS = total dissolved solids
TSS = total suspended solids
μmhos/cm = micromhos per centimeter

distributed, and populations that plot as a straight line in a logarithmic scale are referred to as lognormally distributed.

Probability plots for the baseline data (Appendix H) show the concentration of a chemical in each sample in a manner that also indicates how well the data set for the chemical fits a normal or lognormal distribution. The concentrations of some naturally occurring chemicals follow a lognormal distribution, so the original data were also log-transformed and then plotted to qualitatively assess the fit to a lognormal distribution (distributional tests such as the Shapiro-Wilk test provide a quantitative measure of how well the data fit a particular distribution).

3.3.1.5 Trends in Concentration

Temporal trends in data were evaluated graphically using time-concentration plots (Appendix I) and the Kendall tau test (Appendix E). Appendix J and K provide the data used to perform these analyses. Although extreme values were excluded from the trend analysis, additional outliers that were not obvious on the box-and-whisker plots are apparent in normal probability plots and should be evaluated further and possibly excluded in subsequent evaluations.

The Kendall tau is a nonparametric test that provides a probability indicating whether the arrangement of data over time represent a temporal trend or is due to chance (random). The Kendall tau test was applied for constituents with at least eight samples. A summary of the significant results from the Kendall tau test is presented in Appendix E. The 95 percent probability level (i.e., p-values less than or equal to 0.0500) was set as the statistical indicator of a temporal trend.

3.3.2 Regional Baseline Database Discussion

Regional data to characterize ground water quality are sparse in the Ambrosia Lake Subdistrict. The Section 27 baseline database serves as an approximation of a potential baseline to ground water in the mine voids at the Site because it represents ambient ground water quality in the interconnected ground water system across Ambrosia Lake Valley. However, these data are of unknown quality and the original data records and qualifiers are lacking. Little to no information is available that indicates which part of the water column is represented by the water quality data. In fact, these data could possibly represent sampling locations as diverse as the top of the water column, any location within the water column, or a sample of pumped mine water discharged to the arroyo. Also, there are no data on other specific factors in these mines such as position of the sample relative to stratigraphy, mineralogy, ore deposits, vent hole casing, or stage of ground water recovery, all of which could affect the quality of water measured in a sample.

Box-and-whisker plots are useful to describe and compare distributions of constituents from different mine shafts and other available data for the Westwater Canyon Sandstone. The box-and-whisker plots shown in Appendix F highlight the broad variability of constituent

Appendix E
Summary Statistics for Westwater Canyon Database

Appendix E
Summary Statistics for Baseline Westwater Caynon Database

Analyte	Data Set	Unit	Valid N	Mean	Geometric Mean	Standard Deviation	Mean + 2 Std. Devs.	Upper 95% Confidence	Lower 95% Confidence	Min	Max	Lower Quartile	Median	Upper Quartile	Quartile Range	W-norm	P-norm	W-log	P-log	Distribution
Arsenic	All Data	mg/L	47	0.017	0.003	0.053	0.122	0.032	0.001	0.0005	0.27	0.001	0.0025	0.007	0.2695	0.309	0.000	0.896	0.001	Non-Parametric
Arsenic	No Extremes	mg/L	42	0.004	0.002	0.005	0.013	0.005	0.002	0.0005	0.024	0.0005	0.0025	0.006	0.0235	0.694	0.000	0.908	0.003	Non-Parametric
Bicarbonate	All Data	mg/L	194	267.37	255.51	72.37	412.11	277.62	257.12	38	730	240	276	302	692	0.873	0.000	0.757	0.000	Non-Parametric
Bicarbonate	No Extremes	mg/L	190	265.94	258.18	57.35	380.64	274.15	257.73	57	451	240	276	301	394	0.962	0.000	0.826	0.000	Non-Parametric
Calcium	All Data	mg/L	201	243.70	140.03	161.28	566.25	266.13	221.27	1.6	720	76.4	264	379	718.4	0.930	0.000	0.789	0.000	Non-Parametric
Chloride	All Data	mg/L	535	105.59	42.38	125.08	355.76	116.22	94.97	0.1	603	12	44	170	602.9	0.793	0.000	0.961	0.000	Non-Parametric
Iron	All Data	mg/L	158	1.33	0.12	3.28	7.89	1.84	0.81	0.005	18.8	0.02	0.1	0.4	18.795	0.455	0.000	0.938	0.000	Non-Parametric
Iron	No Extremes	mg/L	134	0.17	0.06	0.28	0.73	0.22	0.12	0.005	1.49	0.02	0.05	0.16	1.485	0.601	0.000	0.967	0.002	Non-Parametric
Magnesium	All Data	mg/L	192	87.45	47.56	65.53	218.51	96.78	78.12	0.1	410	27.3	90.9	130	409.9	0.930	0.000	0.815	0.000	Non-Parametric
Molybdenum	All Data	mg/L	369	0.92	0.45	1.05	3.02	1.03	0.81	0.0005	8.8	0.25	0.5	1.32	8.7995	0.755	0.000	0.914	0.000	Non-Parametric
Molybdenum	No Extremes	mg/L	364	0.85	0.43	0.85	2.56	0.94	0.77	0.0005	4.4	0.25	0.5	1.3	4.3995	0.838	0.000	0.902	0.000	Non-Parametric
pH	All Data	mg/L	166	7.94	7.93	0.51	8.96	8.02	7.87	6.45	9.37	7.69	8	8.3	2.92	0.986	0.089			Normal
Radium 226+228	All Data	pCi/L	402	81.96	45.48	86.17	254.30	90.41	73.51	0.045	809.2	26	59.1	111	809.155	0.751	0.000	0.906	0.000	Non-Parametric
Radium 226+228	No Extremes	pCi/L	398	77.29	44.38	70.69	218.67	84.26	70.33	0.045	359.8	25.91	58.225	110.89	359.755	0.853	0.000	0.895	0.000	Non-Parametric
Selenium	All Data	mg/L	360	0.16	0.04	0.23	0.62	0.18	0.14	0.0005	1.53	0.012	0.0495	0.23	1.5295	0.708	0.000	0.954	0.000	Non-Parametric
Selenium	No Extremes	mg/L	353	0.14	0.04	0.19	0.51	0.16	0.12	0.0005	0.844	0.012	0.046	0.2	0.8435	0.751	0.000	0.947	0.000	Non-Parametric
Sodium	All Data	mg/L	228	281.49	249.13	125.01	531.51	297.81	265.18	18.4	800	180	288	364	781.6	0.954	0.000	0.909	0.000	Non-Parametric
Sulfate	All Data	mg/L	904	1140.64	930.16	538.28	2217.19	1175.77	1105.50	5.8	3030	735.5	1170	1601.75	3024.2	0.975	0.000	0.746	0.000	Non-Parametric
TDS	All Data	mg/L	474	1982.47	1669.40	992.25	3966.97	2072.03	1892.92	6.1	5220	1167	1900	2840	5213.9	0.963	0.000	0.872	0.000	Non-Parametric
U_3O_8	All Data	mg/L	199	9.78	7.42	7.52	24.83	10.84	8.73	0.12	39.3	5	7.8	11.75	39.18	0.835	0.000	0.941	0.000	Non-Parametric
U_3O_8	No Extremes	mg/L	195	9.25	7.18	6.58	22.42	10.18	8.32	0.12	31	5	7.8	11.25	30.88	0.863	0.000	0.931	0.000	Non-Parametric
Uranium	All Data	mg/L	1121	10.87	6.89	8.83	28.53	11.38	10.35	0.0025	51.2	5.5	8.5	12.9	51.1975	0.852	0.000	0.762	0.000	Non-Parametric
Uranium	No Extremes	mg/L	1093	10.11	6.58	7.51	25.12	10.55	9.66	0.0025	34.8	5.4	8.4	12.2	34.7975	0.888	0.000	0.742	0.000	Non-Parametric

Notes:

All Data = All valid records included in the calculation
No Extremes = Calculation redone with the extreme values removed
Valid N = Number of samples
Mean = Arithmetic mean
Mean + 2 Std. Dev. = Arithmetic mean plus two standard deviations
Lower 95% Confidence Interval = The lower value around the mean where the "true" mean can be expected to be located with 95% certainty
Upper 95% Confidence Interval = The upper value around the mean where the "true" mean can be expected to be located with 95% certainty
Min = Minimum detected concentration
Max = Maximum detected concentration
Lower Quartile = 25th percentile of the sample population
Median = 50th percentile of the sample population
Upper Quartile = 75th percentile of the sample population
Quartile Range = Width of the range about the meadian that included 50% of the cases
W-norm = Shapiro-Wilk score for normality
p-norm = p-value from Shapiro-Wilk test for normality, where $p < 0.05$ indicates a non-normal distribution
W-log = Shapiro-Wilk score for log-normality
p-log = p-value from Shapiro-Wilk test for log-normality, where $p < 0.05$ indicates a non-lognormal distribution
Distribution = Type of distribution, based on Shapiro-Wilk test; Normal, Lognormal, and Nonparametric
mg/L = milligrams per liter
pCi/L = picocuries per liter
TDS = Total dissolved solids

Appendix E
Summary Statistics for Baseline Westwater Caynon Database

Analyte	Data Set	Unit	Valid N	Mean	Geometric Mean	Standard Deviation	Mean + 2 Std. Devs.	Upper 95% Confidence	Lower 95% Confidence	Min	Max	Lower Quartile	Median	Upper Quartile	Quartile Range	W-norm	P-norm	W-log	P-log	Distribution
Arsenic	All Data	mg/L	47	0.017	0.003	0.053	0.122	0.032	0.001	0.0005	0.27	0.001	0.0025	0.007	0.2695	0.309	0.000	0.896	0.001	Non-Parametric
Arsenic	No Extremes	mg/L	42	0.004	0.002	0.005	0.013	0.005	0.002	0.0005	0.024	0.0005	0.0025	0.006	0.0235	0.694	0.000	0.908	0.003	Non-Parametric
Bicarbonate	All Data	mg/L	194	267.37	255.51	72.37	412.11	277.62	257.12	38	730	240	276	302	692	0.873	0.000	0.757	0.000	Non-Parametric
Bicarbonate	No Extremes	mg/L	190	265.94	258.18	57.35	380.64	274.15	257.73	57	451	240	276	301	394	0.962	0.000	0.826	0.000	Non-Parametric
Calcium	All Data	mg/L	201	243.70	140.03	161.28	566.25	266.13	221.27	1.6	720	76.4	264	379	718.4	0.930	0.000	0.789	0.000	Non-Parametric
Chloride	All Data	mg/L	535	105.59	42.38	125.08	355.76	116.22	94.97	0.1	603	12	44	170	602.9	0.793	0.000	0.961	0.000	Non-Parametric
Iron	All Data	mg/L	158	1.33	0.12	3.28	7.89	1.84	0.81	0.005	18.8	0.02	0.1	0.4	18.795	0.455	0.000	0.938	0.000	Non-Parametric
Iron	No Extremes	mg/L	134	0.17	0.06	0.28	0.73	0.22	0.12	0.005	1.49	0.02	0.05	0.16	1.485	0.601	0.000	0.967	0.002	Non-Parametric
Magnesium	All Data	mg/L	192	87.45	47.56	65.53	218.51	96.78	78.12	0.1	410	27.3	90.9	130	409.9	0.930	0.000	0.815	0.000	Non-Parametric
Molybdenum	All Data	mg/L	369	0.92	0.45	1.05	3.02	1.03	0.81	0.0005	8.8	0.25	0.5	1.32	8.7995	0.755	0.000	0.914	0.000	Non-Parametric
Molybdenum	No Extremes	mg/L	364	0.85	0.43	0.85	2.56	0.94	0.77	0.0005	4.4	0.25	0.5	1.3	4.3995	0.838	0.000	0.902	0.000	Non-Parametric
pH	All Data	mg/L	166	7.94	7.93	0.51	8.96	8.02	7.87	6.45	9.37	7.69	8	8.3	2.92	0.986	0.089			Normal
Radium 226+228	All Data	pCi/L	402	81.96	45.48	86.17	254.30	90.41	73.51	0.045	809.2	26	59.1	111	809.155	0.751	0.000	0.906	0.000	Non-Parametric
Radium 226+228	No Extremes	pCi/L	398	77.29	44.38	70.69	218.67	84.26	70.33	0.045	359.8	25.91	58.225	110.89	359.755	0.853	0.000	0.895	0.000	Non-Parametric
Selenium	All Data	mg/L	360	0.16	0.04	0.23	0.62	0.18	0.14	0.0005	1.53	0.012	0.0495	0.23	1.5295	0.708	0.000	0.954	0.000	Non-Parametric
Selenium	No Extremes	mg/L	353	0.14	0.04	0.19	0.51	0.16	0.12	0.0005	0.844	0.012	0.046	0.2	0.8435	0.751	0.000	0.947	0.000	Non-Parametric
Sodium	All Data	mg/L	228	281.49	249.13	125.01	531.51	297.81	265.18	18.4	800	180	288	364	781.6	0.954	0.000	0.909	0.000	Non-Parametric
Sulfate	All Data	mg/L	904	1140.64	930.16	538.28	2217.19	1175.77	1105.50	5.8	3030	735.5	1170	1601.75	3024.2	0.975	0.000	0.746	0.000	Non-Parametric
TDS	All Data	mg/L	474	1982.47	1669.40	992.25	3966.97	2072.03	1892.92	6.1	5220	1167	1900	2840	5213.9	0.963	0.000	0.872	0.000	Non-Parametric
U_3O_8	All Data	mg/L	199	9.78	7.42	7.52	24.83	10.84	8.73	0.12	39.3	5	7.8	11.75	39.18	0.835	0.000	0.941	0.000	Non-Parametric
U_3O_8	No Extremes	mg/L	195	9.25	7.18	6.58	22.42	10.18	8.32	0.12	31	5	7.8	11.25	30.88	0.863	0.000	0.931	0.000	Non-Parametric
Uranium	All Data	mg/L	1121	10.87	6.89	8.83	28.53	11.38	10.35	0.0025	51.2	5.5	8.5	12.9	51.1975	0.852	0.000	0.762	0.000	Non-Parametric
Uranium	No Extremes	mg/L	1093	10.11	6.58	7.51	25.12	10.55	9.66	0.0025	34.8	5.4	8.4	12.2	34.7975	0.888	0.000	0.742	0.000	Non-Parametric

Notes:

All Data = All valid records included in the calculation

No Extremes = Calculation redone with the extreme values removed

Valid N = Number of samples

Mean = Arithmetic mean

Mean + 2 Std. Dev. = Arithmetic mean plus two standard deviations

Lower 95% Confidence Interval = The lower value around the mean where the "true" mean can be expected to be located with 95% certainty

Upper 95% Confidence Interval = The upper value around the mean where the "true" mean can be expected to be located with 95% certainty

Min = Minimum detected concentration

Max = Maximum detected concentration

Lower Quartile = 25th percentile of the sample population

Median = 50th percentile of the sample population

Upper Quartile = 75th percentile of the sample population

Quartile Range = Width of the range about the meadian that included 50% of the cases

W-norm = Shapiro-Wilk score for normality

p-norm = p-value from Shapiro-Wilk test for normality, where $p < 0.05$ indicates a non-normal distribution

W-log = Shapiro-Wilk score for log-normality

p-log = p-value from Shapiro-Wilk test for log-normality, where $p < 0.05$ indicates a non-lognormal distribution

Distribution = Type of distribution, based on Shapiro-Wilk test; Normal, Lognormal, and Nonparametric

mg/L = milligrams per liter

pCi/L = picocuries per liter

TDS = Total dissolved solids

New Mexico Office of the State Engineer

Point of Diversion by Location

(quarters are 1=NW 2=NE 3=SW 4=SE)

(acre ft per annum) (quarters are smallest to largest) (NAD83 UTM in meters) (in feet)

WR File Nbr	Use	Diversion	County	POD Number	Source	q q q 64 16 4	Sec	Tws	Rng	X	Y	Start Date	Finish Date	Depth Well	Depth Water
B 00994	MIN	5227	McKinley	B 00994 S-2	Shallow	1 3 2	33	14N	09W	246233	3921153		01/09/1959	848	
B 00376	IND	371	McKinley	B 00376	Artesian	2 4 4	28	14N	09W	246866	3921950	11/11/1956	02/07/1957	3366	
B 00375	IND	93.55	McKinley	B 00375	Artesian	4 3 2	28	14N	09W	246490	3922606	11/16/1956	01/02/1957	801	
B 00994	MIN	5227	McKinley	B 00994 S-3	Shallow	3 4 2	30	14N	09W	243447	3922673		06/08/1958	750	
B 00539	PUB	0	McKinley	B 00539	Shallow	4 2 1	31	14N	09W	242811	3921480				
B 00680	CON	0	McKinley	B 00680	Shallow	4 2 1	31	14N	09W	242811	3921480				
B 01145	HWY	0	McKinley	B 01145		4 2 1	31	14N	09W	242811	3921480				
B 00364	MIN	0	McKinley	B 00364	Artesian	1 2 2	30	14N	09W	243460	3923276		08/31/1956	735	
B 00365	MIN	0	McKinley	B 00365	Artesian	2 3	20	14N	09W	244399	3923952		01/31/1956	793	
B 00994	MIN	5227	McKinley	B 00994 S	Shallow	4 3 1	30	14N	09W	242425	3922703		03/23/1968	810	
B 00522	MON	0	McKinley	B 00522		2 2 4	25	14N	10W	242009	3922518	02/06/1978	02/07/1978	70	
B 00994	MIN	5227	McKinley	B 00994 S-4	Shallow	1 1 4	19	14N	09W	243086	3924087		03/16/1970	779	
B 00993	MIN	4735	McKinley	B 00993	Shallow	4 4 1	35	14N	09W	249261	3920832		07/21/1969	1398	
B 00994	MIN	5227	McKinley	B 00994 S-5	Shallow	4 1 3	17	14N	09W	244128	3925430		04/05/1959	1094	
B 00366	MIN	0	McKinley	B 00366	Artesian	1 4	24	14N	10W	241563	3924043		12/31/1955	760	
B 00994	MIN	5227	McKinley	B 00994	Shallow	3 4 3	24	14N	10W	241046	3923554		09/18/1958	857	
B 00371	MIN	0	McKinley	B 00371		3 1	25	14N	10W	240716	3922861		08/25/1956	752	
B 00993	MIN	4735	McKinley	B 00993 S	Shallow	4 1 3	36	14N	09W	250436	3920388		01/01/1960	1533	
B 01190	STK	3	McKinley	B 01190	Shallow	3 3 3	11	13N	09W	248462	3916872	08/09/1989	08/31/1989	390	37

WR File Nbr	Use	Diversion (acre ft per annum)	County	POD Number	Source	q 64 (quarters are 1=NW 2=NE 3=SW 4=SE) (quarters are smallest to largest)	q 16	q 4	Sec	Tws	Rng	X (NAD83 UTM in meters)	Y	Start Date	Finish Date	Depth Well (in feet)	Depth Water
B 01711	EXP	0	McKinley	B 01711 POD4		4	4	1	36	14N	09W	250847	3920771			2000	
			McKinley	B 01711 POD3		3	4	2	36	14N	09W	251436	3920765			2000	
			McKinley	B 01711 POD5		1	2	4	36	14N	09W	251425	3920568			2000	
B 01115	DOM	3	McKinley	B 01115	Shallow	4	4	3	15	13N	09W	247430	3915312	07/19/1986	07/21/1986	478	204
B 01636	DOM	3	McKinley	B 01636	Shallow		2	1	22	13N	09W	247216	3915204	04/27/2005	05/10/2005	260	80

Record Count: 24

U.S. Census Bureau

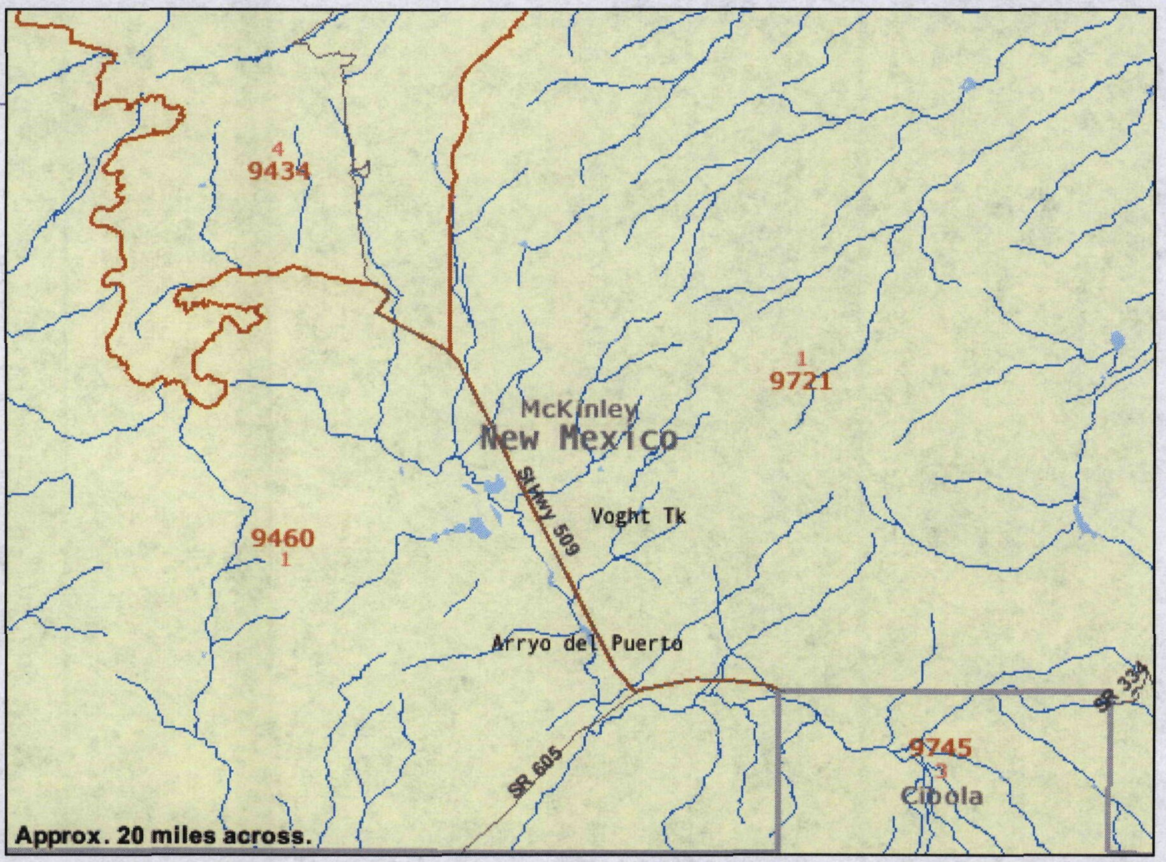
American FactFinder

Legend

Boundaries
- State
- '00 County
- '00 Census Tract
- '00 Block Group
- '00 Block
- '00 Place
- '00 Place
- '00 Urban Area
- '00 Urban Area

Features
- Major Road
- Street
- Stream/Waterbody
- Stream/Waterbody

Items in gray text are not visible at this zoom level



U.S. Census Bureau
American FactFinder
Main Search Feedback FAQs Glossary Site Map Help

P1. TOTAL POPULATION [1] - Universe: Total population
Data Set: Census 2000 Summary File 1 (SF 1) 100-Percent Data

NOTE: For information on confidentiality protection, nonsampling error, definitions, and count corrections see http://factfinder.census.gov/home/en/datanotes/expsf1u.htm.

	Block Group 1, Census Tract 9721, McKinley County, New Mexico
Total	7

U.S. Census Bureau
Census 2000

Census count corrections for American Indian and Alaska Native Areas (AIANAs), states, counties, places, county subdivisions, census tracts, and blocks may have been released as a result of an external challenge through the Count Question Resolution Program.

Standard Error/Variance documentation for this dataset:
Accuracy of the Data: Census 2000 Summary File 1 (SF 1) 100-Percent Data (PDF 44KB)

Total of 8 people
in 4-mile radius of

COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980

"SUPERFUND"

Q:\COMP\ENVIR2\CERCLA

December 31, 2002

[As Amended Through P.L. 107–377, December 31, 2002]

TABLE OF CONTENTS FOR COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980 (SUPERFUND)[1]

TITLE I—HAZARDOUS SUBSTANCES RELEASES, LIABILITY, COMPENSATION

[1] This table of contents is not part of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 but is set forth for the convenience of the users of this publication.

TITLE IV—POLLUTION INSURANCE

COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980 (SUPERFUND)[1]

AN ACT To provide for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive hazardous waste disposal sites.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Comprehensive Environmental Response, Compensation, and Liability Act of 1980".

TITLE I—HAZARDOUS SUBSTANCES RELEASES, LIABILITY, COMPENSATION

DEFINITIONS

SEC. 101. For purpose of this title—

(1) The term "act of God" means an unanticipated grave natural disaster or other natural phenomenon of an exceptional, inevitable, and irresistible character, the effects of which could not have been prevented or avoided by the exercise of due care or foresight.

(2) The term "Administrator" means the Administrator of the United States Environmental Protection Agency.

(3) The term "barrel" means forty-two United States gallons at sixty degrees Fahrenheit.

(4) The term "claim" means a demand in writing for a sum certain.

(5) The term "claimant" means any person who presents a claim for compensation under this Act.

(6) The term "damages" means damages for injury or loss of natural resources as set forth in section 107(a) or 111(b) of this Act.

(7) The term "drinking water supply" means any raw or finished water source that is or may be used by a public water system (as defined in the Safe Drinking Water Act) or as drinking water by one or more individuals.

(8) The term "environment" means (A) the navigable waters, the waters of the contiguous zone, and the ocean waters of which the natural resources are under the exclusive management authority of the United States under the Fishery Conservation and Management Act of 1976, and (B) any other surface water, ground water, drinking water supply, land surface or subsurface strata, or ambient air within the United States or under the jurisdiction of the United States.

[1] The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (42 U.S.C. 9601–9675), commonly known as "Superfund," consists of Public Law 96–510 (Dec. 11, 1980) and the amendments made by subsequent enactments.

(9) The term "facility" means (A) any building, structure, installation, equipment, pipe or pipeline (including any pipe into a sewer or publicly owned treatment works), well, pit, pond, lagoon, impoundment, ditch, landfill, storage container, motor vehicle, rolling stock, or aircraft, or (B) any site or area where a hazardous substance has been deposited, stored, disposed of, or placed, or otherwise come to be located; but does not include any consumer product in consumer use or any vessel.

(10) The term "federally permitted release" means (A) discharges in compliance with a permit under section 402 of the Federal Water Pollution Control Act, (B) discharges resulting from circumstances identified and reviewed and made part of the public record with respect to a permit issued or modified under section 402 of the Federal Water Pollution Control Act and subject to a condition of such permit, (C) continuous or anticipated intermittent discharges from a point source, identified in a permit or permit application under section 402 of the Federal Water Pollution Control Act, which are caused by events occurring within the scope of relevant operating or treatment systems, (D) discharges in compliance with a legally enforceable permit under section 404 of the Federal Water Pollution Control Act, (E) releases in compliance with a legally enforceable final permit issued pursuant to section 3005 (a) through (d) of the Solid Waste Disposal Act from a hazardous waste treatment, storage, or disposal facility when such permit specifically identifies the hazardous substances and makes such substances subject to a standard of practice, control procedure or bioassay limitation or condition, or other control on the hazardous substances in such releases, (F) any release in compliance with a legally enforceable permit issued under section 102 of[1] section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972, (G) any injection of fluids authorized under Federal underground injection control programs or State programs submitted for Federal approval (and not disapproved by the Administrator of the Environmental Protection Agency) pursuant to part C of the Safe Drinking Water Act, (H) any emission into the air subject to a permit or control regulation under section 111, section 112, title I part C, title I part D, or State implementation plans submitted in accordance with section 110 of the Clean Air Act (and not disapproved by the Administrator of the Environmental Protection Agency), including any schedule or waiver granted, promulgated, or approved under these sections, (I) any injection of fluids or other materials authorized under applicable State law (i) for the purpose of stimulating or treating wells for the production of crude oil, natural gas, or water, (ii) for the purpose of secondary, tertiary, or other enhanced recovery of crude oil or natural gas, or (iii) which are brought to the surface in conjunction with the production of crude oil or natural gas and which are reinjected, (J) the introduction of any pollutant into a publicly owned treatment works when such pollutant is specified in and in

[1] So in law. Probably should be "or".

compliance with applicable pretreatment standards of section 307 (b) or (c) of the Clean Water Act and enforceable requirements in a pretreatment program submitted by a State or municipality for Federal approval under section 402 of such Act, and (K) any release of source, special nuclear, or byproduct material, as those terms are defined in the Atomic Energy Act of 1954, in compliance with a legally enforceable license, permit, regulation, or order issued pursuant to the Atomic Energy Act of 1954.

(11) The term "Fund" or "Trust Fund" means the Hazardous Substance Response Fund established by section 221 [1] of this Act or, in the case of a hazardous waste disposal facility for which liability has been transferred under section 107(k) of this Act, the Post-closure Liability Fund established by section 232 [1] of this Act.

(12) The term "ground water" means water in a saturated zone or stratum beneath the surface of land or water.

(13) The term "guarantor" means any person, other than the owner or operator, who provides evidence of financial responsibility for an owner or operator under this Act.

(14) The term "hazardous substance" means (A) any substance designated pursuant to section 311(b)(2)(A) of the Federal Water Pollution Control Act, (B) any element, compound, mixture, solution, or substance designated pursuant to section 102 of this Act, (C) any hazardous waste having the characteristics identified under or listed pursuant to section 3001 of the Solid Waste Disposal Act (but not including any waste the regulation of which under the Solid Waste Disposal Act has been suspended by Act of Congress), (D) any toxic pollutant listed under section 307(a) of the Federal Water Pollution Control Act, (E) any hazardous air pollutant listed under section 112 of the Clean Air Act, and (F) any imminently hazardous chemical substance or mixture with respect to which the Administrator has taken action pursuant to section 7 of the Toxic Substances Control Act. The term does not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under subparagraphs (A) through (F) of this paragraph, and the term does not include natural gas, natural gas liquids, liquefied natural gas, or synthetic gas usable for fuel (or mixtures of natural gas and such synthetic gas).

(15) The term "navigable waters" or "navigable waters of the United States" means the waters of the United States, including the territorial seas.

(16) The term "natural resources" means land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States (including the resources of the fishery conservation zone established by the Fishery Conservation and Management Act of 1976), any State, local government, or any foreign govern-

[1] Sections 221 and 232 were repealed by sections 517(c)(1) and 514(b), repsectively, of Public Law 99–499.

ment, any Indian tribe, or, if such resources are subject to a trust restriction or alienation, any member of an Indian tribe.

(17) The term "offshore facility" means any facility of any kind located in, on, or under, any of the navigable waters of the United States, and any facility of any kind which is subject to the jurisdiction of the United States and is located in, on, or under any other waters, other than a vessel or a public vessel.

(18) The term "onshore facility" means any facility (including, but not limited to, motor vehicles and rolling stock) of any kind located in, on, or under, any land or nonnavigable waters within the United States.

(19) The term "otherwise subject to the jurisdiction of the United States" means subject to the jurisdiction of the United States by virtue of United States citizenship, United States vessel documentation or numbering, or as provided by international agreement to which the United States is a party.

(20)(A) The term "owner or operator" means (i) in the case of a vessel, any person owning, operating, or chartering by demise, such vessel, (ii) in the case of an onshore facility or an offshore facility, any person owning or operating such facility, and (iii) in the case of any facility, title or control of which was conveyed due to bankruptcy, foreclosure, tax delinquency, abandonment, or similar means to a unit of State or local government, any person who owned, operated, or otherwise controlled activities at such facility immediately beforehand. Such term does not include a person, who, without participating in the management of a vessel or facility, holds indicia of ownership primarily to protect his security interest in the vessel or facility.

(B) In the case of a hazardous substance which has been accepted for transportation by a common or contract carrier and except as provided in section 107(a) (3) or (4) of this Act, (i) the term "owner or operator" shall mean such common carrier or other bona fide for hire carrier acting as an independent contractor during such transportation, (ii) the shipper of such hazardous substance shall not be considered to have caused or contributed to any release during such transportation which resulted solely from circumstances or conditions beyond his control.

(C) In the case of a hazardous substance which has been delivered by a common or contract carrier to a disposal or treatment facility and except as provided in section 107(a) (3) or (4) (i) the term "owner or operator" shall not include such common or contract carrier, and (ii) such common or contract carrier shall not be considered to have caused or contributed to any release at such disposal or treatment facility resulting from circumstances or conditions beyond its control.

(D) The term "owner or operator" does not include a unit of State or local government which acquired ownership or control involuntarily[1] through seizure or otherwise in connection

[1] Section 427 of Public Law 106–74 (113 Stat. 1095) added the phrase "through seizure or otherwise in connection with law enforcement activity" before "involuntary" the first place it appears. It was inserted after "involuntarily" as the probable intent of Congress.

with law enforcement activity through bankruptcy, tax delinquency, abandonment, or other circumstances in which the government involuntarily acquires title by virtue of its function as sovereign. The exclusion provided under this paragraph shall not apply to any State or local government which has caused or contributed to the release or threatened release of a hazardous substance from the facility, and such a State or local government shall be subject to the provisions of this Act in the same manner and to the same extent, both procedurally and substantively, as any nongovernmental entity, including liability under section 107.

(E)[1] EXCLUSION OF LENDERS NOT PARTICIPANTS IN MANAGEMENT.—

(i) INDICIA OF OWNERSHIP TO PROTECT SECURITY.— The term "owner or operator" does not include a person that is a lender that, without participating in the management of a vessel or facility, holds indicia of ownership primarily to protect the security interest of the person in the vessel or facility.

(ii) FORECLOSURE.—The term "owner or operator" does not include a person that is a lender that did not participate in management of a vessel or facility prior to foreclosure, notwithstanding that the person—

(I) forecloses on the vessel or facility; and

(II) after foreclosure, sells, re-leases (in the case of a lease finance transaction), or liquidates the vessel or facility, maintains business activities, winds up operations, undertakes a response action under section 107(d)(1) or under the direction of an on-scene coordinator appointed under the National Contingency Plan, with respect to the vessel or facility, or takes any other measure to preserve, protect, or prepare the vessel or facility prior to sale or disposition,

if the person seeks to sell, re-lease (in the case of a lease finance transaction), or otherwise divest the person of the vessel or facility at the earliest practicable, commercially reasonable time, on commercially reasonable terms, taking into account market conditions and legal and regulatory requirements.

(F) PARTICIPATION IN MANAGEMENT.—For purposes of subparagraph (E)—

(i) the term "participate in management"—

(I) means actually participating in the management or operational affairs of a vessel or facility; and

(II) does not include merely having the capacity to influence, or the unexercised right to control, vessel or facility operations;

(ii) a person that is a lender and that holds indicia of ownership primarily to protect a security interest in a vessel or facility shall be considered to participate in

[1] So in law. Indentation of subparagraphs (E) through (G) is incorrect.

management only if, while the borrower is still in possession of the vessel or facility encumbered by the security interest, the person—

(I) exercises decisionmaking control over the environmental compliance related to the vessel or facility, such that the person has undertaken responsibility for the hazardous substance handling or disposal practices related to the vessel or facility; or

(II) exercises control at a level comparable to that of a manager of the vessel or facility, such that the person has assumed or manifested responsibility—

(aa) for the overall management of the vessel or facility encompassing day-to-day decisionmaking with respect to environmental compliance; or

(bb) over all or substantially all of the operational functions (as distinguished from financial or administrative functions) of the vessel or facility other than the function of environmental compliance;

(iii) the term "participate in management" does not include performing an act or failing to act prior to the time at which a security interest is created in a vessel or facility; and

(iv) the term "participate in management" does not include—

(I) holding a security interest or abandoning or releasing a security interest;

(II) including in the terms of an extension of credit, or in a contract or security agreement relating to the extension, a covenant, warranty, or other term or condition that relates to environmental compliance;

(III) monitoring or enforcing the terms and conditions of the extension of credit or security interest;

(IV) monitoring or undertaking 1 or more inspections of the vessel or facility;

(V) requiring a response action or other lawful means of addressing the release or threatened release of a hazardous substance in connection with the vessel or facility prior to, during, or on the expiration of the term of the extension of credit;

(VI) providing financial or other advice or counseling in an effort to mitigate, prevent, or cure default or diminution in the value of the vessel or facility;

(VII) restructuring, renegotiating, or otherwise agreeing to alter the terms and conditions of the extension of credit or security interest, exercising forbearance;

(VIII) exercising other remedies that may be available under applicable law for the breach of a term or condition of the extension of credit or security agreement; or

(IX) conducting a response action under section 107(d) or under the direction of an on-scene coordinator appointed under the National Contingency Plan,

if the actions do not rise to the level of participating in management (within the meaning of clauses (i) and (ii)).

(G) OTHER TERMS.—As used in this Act:

(i) EXTENSION OF CREDIT.—The term "extension of credit" includes a lease finance transaction—

(I) in which the lessor does not initially select the leased vessel or facility and does not during the lease term control the daily operations or maintenance of the vessel or facility; or

(II) that conforms with regulations issued by the appropriate Federal banking agency or the appropriate State bank supervisor (as those terms are defined in section 3 of the Federal Deposit Insurance Act (12 U.S.C. 1813) [1] or with regulations issued by the National Credit Union Administration Board, as appropriate.

(ii) FINANCIAL OR ADMINISTRATIVE FUNCTION.—The term "financial or administrative function" includes a function such as that of a credit manager, accounts payable officer, accounts receivable officer, personnel manager, comptroller, or chief financial officer, or a similar function.

(iii) FORECLOSURE; FORECLOSE.—The terms "foreclosure" and "foreclose" mean, respectively, acquiring, and to acquire, a vessel or facility through—

(I)(aa) purchase at sale under a judgment or decree, power of sale, or nonjudicial foreclosure sale;

(bb) a deed in lieu of foreclosure, or similar conveyance from a trustee; or

(cc) repossession,

if the vessel or facility was security for an extension of credit previously contracted;

(II) conveyance pursuant to an extension of credit previously contracted, including the termination of a lease agreement; or

(III) any other formal or informal manner by which the person acquires, for subsequent disposition, title to or possession of a vessel or facility in order to protect the security interest of the person.

(iv) LENDER.—The term "lender" means—

[1] So in law. Probably should read "1813))".

(I) an insured depository institution (as defined in section 3 of the Federal Deposit Insurance Act (12 U.S.C. 1813));

(II) an insured credit union (as defined in section 101 of the Federal Credit Union Act (12 U.S.C. 1752));

(III) a bank or association chartered under the Farm Credit Act of 1971 (12 U.S.C. 2001 et seq.);

(IV) a leasing or trust company that is an affiliate of an insured depository institution;

(V) any person (including a successor or assignee of any such person) that makes a bona fide extension of credit to or takes or acquires a security interest from a nonaffiliated person;

(VI) the Federal National Mortgage Association, the Federal Home Loan Mortgage Corporation, the Federal Agricultural Mortgage Corporation, or any other entity that in a bona fide manner buys or sells loans or interests in loans;

(VII) a person that insures or guarantees against a default in the repayment of an extension of credit, or acts as a surety with respect to an extension of credit, to a nonaffiliated person; and

(VIII) a person that provides title insurance and that acquires a vessel or facility as a result of assignment or conveyance in the course of underwriting claims and claims settlement.

(v) OPERATIONAL FUNCTION.—The term "operational function" includes a function such as that of a facility or plant manager, operations manager, chief operating officer, or chief executive officer.

(vi) SECURITY INTEREST.—The term "security interest" includes a right under a mortgage, deed of trust, assignment, judgment lien, pledge, security agreement, factoring agreement, or lease and any other right accruing to a person to secure the repayment of money, the performance of a duty, or any other obligation by a nonaffiliated person.

(21) The term "person" means an individual, firm, corporation, association, partnership, consortium, joint venture, commercial entity, United States Government, State, municipality, commission, political subdivision of a State, or any interstate body.

(22) The term "release" means any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment (including the abandonment or discarding of barrels, containers, and other closed receptacles containing any hazardous substance or pollutant or contaminant), but excludes (A) any release which results in exposure to persons solely within a workplace, with respect to a claim which such persons may assert against the employer of such persons, (B) emissions from the engine exhaust of a motor vehicle, rolling stock, aircraft,

vessel, or pipeline pumping station engine, (C) release of source, byproduct, or special nuclear material from a nuclear incident, as those terms are defined in the Atomic Energy Act of 1954, if such release is subject to requirements with respect to financial protection established by the Nuclear Regulatory Commission under section 170 of such Act, or, for the purposes of section 104 of this title or any other response action, any release of source byproduct, or special nuclear material from any processing site designated under section 102(a)(1) or 302(a) of the Uranium Mill Tailings Radiation Control Act of 1978, and (D) the normal application of fertilizer.

(23) The terms[1] "remove" or "removal" means the cleanup or removal of released hazardous substances from the environment, such actions as may be necessary taken in the event of the threat of release of hazardous substances into the environment, such actions as may be necessary to monitor, assess, and evaluate the release or threat of release of hazardous substances, the disposal of removed material, or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release. The term includes, in addition, without being limited to, security fencing or other measures to limit access, provision of alternative water supplies, temporary evacuation and housing of threatened individuals not otherwise provided for, action taken under section 104(b) of this Act, and any emergency assistance which may be provided under the Disaster Relief and Emergency Assistance Act.[2]

(24) The terms[1] "remedy" or "remedial action" means those actions consistent with permanent remedy taken instead of or in addition to removal actions in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment. The term includes, but is not limited to, such actions at the location of the release as storage, confinement, perimeter protection using dikes, trenches, or ditches, clay cover, neutralization, cleanup of released hazardous substances and associated contaminated materials, recycling or reuse, diversion, destruction, segregation of reactive wastes, dredging or excavations, repair or replacement of leaking containers, collection of leachate and runoff, onsite treatment or incineration, provision of alternative water supplies, and any monitoring reasonably required to assure that such actions protect the public health and welfare and the environment. The term includes the costs of permanent relocation of residents and businesses and community facilities where the President determines that, alone or in combination with other measures, such relocation is more cost-effective than and environmentally preferable to

[1] So in law. Probably should be "term".

[2] So in law. Probably should refer to the "Robert T. Stafford Disaster Relief and Emergency Assistance Act", pursuant to the amendment to the short title of such Act made by section 102 of Public Law 100–707.

(3) At any time prior to the date which occurs fifty years after the date of enactment of this Act, any person identified under paragraph (1) of this subsection may apply to the Administrator of the Environmental Protection Agency for a waiver of the provisions of the first sentence of paragraph (2) of this subsection. The Administrator is authorized to grant such waiver if, in his discretion, such waiver would not unreasonably interfere with the attainment of the purposes and provisions of this Act. The Administrator shall promulgate rules and regulations regarding such a waiver so as to inform parties of the proper application procedure and conditions for approval of such a waiver.

(4) Notwithstanding the provisions of this subsection, the Administrator of the Environmental Protection Agency may in his discretion require any such person to retain any record identified pursuant to paragraph (1) of this subsection for such a time period in excess of the period specified in paragraph (2) of this subsection as the Administrator determines to be necessary to protect the public health or welfare.

(e) This section shall not apply to the application of a pesticide product registered under the Federal Insecticide, Fungicide, and Rodenticide Act or to the handling and storage of such a pesticide product by an agricultural producer.

(f) No notification shall be required under subsection (a) or (b) of this section for any release of a hazardous substance—

(1) which is required to be reported (or specifically exempted from a requirement for reporting) under subtitle C of the Solid Waste Disposal Act or regulations thereunder and which has been reported to the National Response Center, or

(2) which is a continuous release, stable in quantity and rate, and is—

(A) from a facility for which notification has been given under subsection (c) of this section, or

(B) a release of which notification has been given under subsections (a) and (b) of this section for a period sufficient to establish the continuity, quantity, and regularity of such release:

Provided, That notification in accordance with subsections (a) and (b) of this paragraph shall be given for releases subject to this paragraph annually, or at such time as there is any statistically significant increase in the quantity of any hazardous substance or constituent thereof released, above that previously reported or occurring.

[42 U.S.C. 9603]

RESPONSE AUTHORITIES

SEC. 104. (a)(1) Whenever (A) any hazardous substance is released or there is a substantial threat of such a release into the environment, or (B) there is a release or substantial threat of release into the environment of any pollutant or contaminant which may present an imminent and substantial danger to the public health or welfare, the President is authorized to act, consistent with the national contingency plan, to remove or arrange for the removal of, and provide for remedial action relating to such hazardous substance, pollutant, or contaminant at any time (including its removal from any contaminated natural resource), or take any other response measure consistent with the national contingency plan which the President deems necessary to protect the public health or welfare or the environment. When the President determines that such action will be done properly and promptly by the owner or operator of the facility or vessel or by any other responsible party, the President may allow such person to carry out the action, conduct the remedial investigation, or conduct the feasibility study in accordance with section 122. No remedial investigation or feasibility study (RI/FS) shall be authorized except on a determination by the President that the party is qualified to conduct the RI/FS and only if the President contracts with or arranges for a qualified person to assist the President in overseeing and reviewing the conduct of such RI/FS and if the responsible party agrees to reimburse the Fund for any cost incurred by the President under, or in connection with, the oversight contract or arrangement. In no event shall a potentially responsible party be subject to a lesser standard of liability, receive preferential treatment, or in any other way, whether direct or indirect, benefit from any such arrangements as a response action contractor, or as a person hired or retained by such a response action contractor, with respect to the release or facility in question. The President shall give primary attention to those releases which the President deems may present a public health threat.

(2) REMOVAL ACTION.—Any removal action undertaken by the President under this subsection (or by any other person referred to in section 122) should, to the extent the President deems practicable, contribute to the efficient performance of any long term remedial action with respect to the release or threatened release concerned.

(3) LIMITATIONS ON RESPONSE.—The President shall not provide for a removal or remedial action under this section in response to a release or threat of release—

(A) of a naturally occurring substance in its unaltered form, or altered solely through naturally occurring processes or phenomena, from a location where it is naturally found;

(B) from products which are part of the structure of, and result in exposure within, residential buildings or business or community structures; or

(C) into public or private drinking water supplies due to deterioration of the system through ordinary use.

(4) EXCEPTION TO LIMITATIONS.—Notwithstanding paragraph (3) of this subsection, to the extent authorized by this section, the President may respond to any release or threat of release if in the President's discretion, it constitutes a public health or environmental emergency and no other person with the authority and capability to respond to the emergency will do so in a timely manner.

(b)(1) INFORMATION; STUDIES AND INVESTIGATIONS.—Whenever the President is authorized to act pursuant to subsection (a) of this section, or whenever the President has reason to believe that a release has occurred or is about to occur, or that illness, disease, or complaints thereof may be attributable to exposure to a hazardous substance, pollutant, or contaminant and that a release may have occurred or be occurring, he may undertake such investigations, monitoring, surveys, testing, and other information gathering as he may deem necessary or appropriate to identify the existence and extent of the release or threat thereof, the source and nature of the hazardous substances, pollutants or contaminants involved, and the extent of danger to the public health or welfare or to the environment. In addition, the President may undertake such planning, legal, fiscal, economic, engineering, architectural, and other studies or investigations as he may deem necessary or appropriate to plan and direct response actions, to recover the costs thereof, and to enforce the provisions of this Act.

(2) COORDINATION OF INVESTIGATIONS.—The President shall promptly notify the appropriate Federal and State natural resource trustees of potential damages to natural resources resulting from releases under investigation pursuant to this section and shall seek to coordinate the assessments, investigations, and planning under this section with such Federal and State trustees.

(c)(1) Unless (A) the President finds that (i) continued response actions are immediately required to prevent, limit, or mitigate an emergency, (ii) there is an immediate risk to public health or welfare or the environment, and (iii) such assistance will not otherwise be provided on a timely basis, or (B) the President has determined the appropriate remedial actions pursuant to paragraph (2) of this subsection and the State or States in which the source of the release is located have complied with the requirements of paragraph (3) of this subsection, or (C) continued response action is otherwise appropriate and consistent with the remedial action to be taken[1] obligations from the Fund, other than those authorized by subsection (b) of this section, shall not continue after $2,000,000 has been obligated for response actions or 12 months has elapsed from the date of initial response to a release or threatened release of hazardous substances.

(2) The President shall consult with the affected State or States before determining any appropriate remedial action to be taken pursuant to the authority granted under subsection (a) of this section.

(3) The President shall not provide any remedial actions pursuant to this section unless the State in which the release occurs first enters into a contract or cooperative agreement with the President providing assurances deemed adequate by the President that (A) the State will assure all future maintenance of the removal and remedial actions provided for the expected life of such actions as determined by the President; (B) the State will assure the availability of a hazardous waste disposal facility acceptable to the President and in compliance with the requirements of subtitle C of the Solid Waste Disposal Act for any necessary offsite storage, destruction, treatment, or secure disposition of the hazardous substances; and (C) the State will pay or assure payment of (i) 10 per centum of the costs of the remedial action, including all future maintenance, or (ii) 50 percent (or such greater amount as the President may determine appropriate, taking into account the degree of responsibility of the State or political subdivision for the release) of any

[1] So in law. Probably should be followed by a comma.

sums expended in response to a release at a facility, that was operated by the State or a political subdivision thereof, either directly or through a contractual relationship or otherwise, at the time of any disposal of hazardous substances therein. For the purpose of clause (ii) of this subparagraph, the term "facility" does not include navigable waters or the beds underlying those waters. The President shall grant the State a credit against the share of the costs for which it is responsible under this paragraph for any documented direct out-of-pocket non-Federal funds expended or obligated by the State or a political subdivision thereof after January 1, 1978, and before the date of enactment of this Act for cost-eligible response actions and claims for damages compensable under section 111 of this title relating to the specific release in question: *Provided, however,* That in no event shall the amount of the credit granted exceed the total response costs relating to the release. In the case of remedial action to be taken on land or water held by an Indian tribe, held by the United States in trust for Indians, held by a member of an Indian tribe (if such land or water is subject to a trust restriction on alienation), or otherwise within the borders of an Indian reservation, the requirements of this paragraph for assurances regarding future maintenance and cost-sharing shall not apply, and the President shall provide the assurance required by this paragraph regarding the availability of a hazardous waste disposal facility.

(4) SELECTION OF REMEDIAL ACTION.—The President shall select remedial actions to carry out this section in accordance with section 121 of this Act (relating to cleanup standards).

(5) STATE CREDITS.—

(A) GRANTING OF CREDIT.—The President shall grant a State a credit against the share of the costs, for which it is responsible under paragraph (3) with respect to a facility listed on the National Priorities List under the National Contingency Plan, for amounts expended by a State for remedial action at such facility pursuant to a contract or cooperative agreement with the President. The credit under this paragraph shall be limited to those State expenses which the President determines to be reasonable, documented, direct out-of-pocket expenditures of non-Federal funds.

(B) EXPENSES BEFORE LISTING OR AGREEMENT.—The credit under this paragraph shall include expenses for remedial action at a facility incurred before the listing of the facility on the National Priorities List or before a contract or cooperative agreement is entered into under subsection (d) for the facility if—

(i) after such expenses are incurred the facility is listed on such list and a contract or cooperative agreement is entered into for the facility, and

(ii) the President determines that such expenses would have been credited to the State under subparagraph (A) had the expenditures been made after listing of the facility on such list and after the date on which such contract or cooperative agreement is entered into.

(C) RESPONSE ACTIONS BETWEEN 1978 AND 1980.—The credit under this paragraph shall include funds expended or obligated by the State or a political subdivision thereof after January 1, 1978, and before December 11, 1980, for cost-eligible response actions and claims for damages compensable under section 111.

(D) STATE EXPENSES AFTER DECEMBER 11, 1980, IN EXCESS OF 10 PERCENT OF COSTS.—The credit under this paragraph shall include 90 percent of State expenses incurred at a facility owned, but not operated, by such State or by a political subdivision thereof. Such credit applies only to expenses incurred pursuant to a contract or cooperative agreement under subsection (d) and only to expenses incurred after December 11, 1980, but before the date of the enactment of this paragraph.

(E) ITEM-BY-ITEM APPROVAL.—In the case of expenditures made after the date of the enactment of this paragraph, the President may require prior approval of each item of expenditure as a condition of granting a credit under this paragraph.

(F) USE OF CREDITS.—Credits granted under this paragraph for funds expended with respect to a facility may be used by the State to reduce all or part of the share of costs otherwise required to be paid by the State under paragraph (3) in connection with remedial actions at such facility. If the amount of funds for which credit is allowed under this paragraph exceeds such share of costs for such facility, the State may use the amount of such excess to reduce all or part of the share of such costs at other facilities in that State. A credit shall not entitle the State to any direct payment.

(6) OPERATION AND MAINTENANCE.—For the purposes of paragraph (3) of this subsection, in the case of ground or surface water contamination, completed remedial action includes the completion of treatment or other measures, whether taken onsite or offsite, necessary to restore ground and surface water quality to a level that assures protection of human health and the environment. With respect to such measures, the operation of such measures for a period of up to 10 years after the construction or installation and commencement of operation shall be considered remedial action. Activities required to maintain the effectiveness of such measures following such period or the completion of remedial action, whichever is earlier, shall be considered operation or maintenance.

(7) LIMITATION ON SOURCE OF FUNDS FOR O&M.—During any period after the availability of funds received by the Hazardous Substance Superfund established under subchapter A of chapter 98 of the Internal Revenue Code of 1954 from tax revenues or appropriations from general revenues, the Federal share of the payment of the cost of operation or maintenance pursuant to paragraph (3)(C)(i) or paragraph (6) of this subsection (relating to operation and maintenance) shall be from funds received by the Hazardous Substance Superfund from amounts recovered on behalf of such fund under this Act.

(8) RECONTRACTING.—The President is authorized to undertake or continue whatever interim remedial actions the President determines to be appropriate to reduce risks to public health or the environment where the performance of a complete remedial action requires recontracting because of the discovery of sources, types, or quantities of hazardous substances not known at the time of entry

into the original contract. The total cost of interim actions undertaken at a facility pursuant to this paragraph shall not exceed $2,000,000.

(9) SITING.—Effective 3 years after the enactment of the Superfund Amendments and Reauthorization Act of 1986, the President shall not provide any remedial actions pursuant to this section unless the State in which the release occurs first enters into a contract or cooperative agreement with the President providing assurances deemed adequate by the President that the State will assure the availability of hazardous waste treatment or disposal facilities which—

(A) have adequate capacity for the destruction, treatment, or secure disposition of all hazardous wastes that are reasonably expected to be generated within the State during the 20-year period following the date of such contract or cooperative agreement and to be disposed of, treated, or destroyed,

(B) are within the State or outside the State in accordance with an interstate agreement or regional agreement or authority,

(C) are acceptable to the President, and

(D) are in compliance with the requirements of subtitle C of the Solid Waste Disposal Act.

(d)(1) COOPERATIVE AGREEMENTS.—

(A) STATE APPLICATIONS.—A State or political subdivision thereof or Indian tribe may apply to the President to carry out actions authorized in this section. If the President determines that the State or political subdivision or Indian tribe has the capability to carry out any or all of such actions in accordance with the criteria and priorities established pursuant to section 105(a)(8) and to carry out related enforcement actions, the President may enter into a contract or cooperative agreement with the State or political subdivision or Indian tribe to carry out such actions. The President shall make a determination regarding such an application within 90 days after the President receives the application.

(B) TERMS AND CONDITIONS.—A contract or cooperative agreement under this paragraph shall be subject to such terms and conditions as the President may prescribe. The contract or cooperative agreement may cover a specific facility or specific facilities.

(C) REIMBURSEMENTS.—Any State which expended funds during the period beginning September 30, 1985, and ending on the date of the enactment of this subparagraph for response actions at any site included on the National Priorities List and subject to a cooperative agreement under this Act shall be reimbursed for the share of costs of such actions for which the Federal Government is responsible under this Act.

(2) If the President enters into a cost-sharing agreement pursuant to subsection (c) of this section or a contract or cooperative agreement pursuant to this subsection, and the State or political subdivision thereof fails to comply with any requirements of the contract, the President may, after providing sixty days notice, seek in the appropriate Federal district court to enforce the contract or

to recover any funds advanced or any costs incurred because of the breach of the contract by the State or political subdivision.

(3) Where a State or a political subdivision thereof is acting in behalf of the President, the President is authorized to provide technical and legal assistance in the administration and enforcement of any contract or subcontract in connection with response actions assisted under this title, and to intervene in any civil action involving the enforcement of such contract or subcontract.

(4) Where two or more noncontiguous facilities are reasonably related on the basis of geography, or on the basis of the threat, or potential threat to the public health or welfare or the environment, the President may, in his discretion, treat these related facilities as one for purposes of this section.

(e) INFORMATION GATHERING AND ACCESS.—

(1) ACTION AUTHORIZED.—Any officer, employee, or representative of the President, duly designated by the President, is authorized to take action under paragraph (2), (3), or (4) (or any combination thereof) at a vessel, facility, establishment, place, property, or location or, in the case of paragraph (3) or (4), at any vessel, facility, establishment, place, property, or location which is adjacent to the vessel, facility, establishment, place, property, or location referred to in such paragraph (3) or (4). Any duly designated officer, employee, or representative of a State or political subdivision under a contract or cooperative agreement under subsection (d)(1) is also authorized to take such action. The authority of paragraphs (3) and (4) may be exercised only if there is a reasonable basis to believe there may be a release or threat of release of a hazardous substance or pollutant or contaminant. The authority of this subsection may be exercised only for the purposes of determining the need for response, or choosing or taking any response action under this title, or otherwise enforcing the provisions of this title.

(2) ACCESS TO INFORMATION.—Any officer, employee, or representative described in paragraph (1) may require any person who has or may have information relevant to any of the following to furnish, upon reasonable notice, information or documents relating to such matter:

(A) The identification, nature, and quantity of materials which have been or are generated, treated, stored, or disposed of at a vessel or facility or transported to a vessel or facility.

(B) The nature or extent of a release or threatened release of a hazardous substance or pollutant or contaminant at or from a vessel or facility.

(C) Information relating to the ability of a person to pay for or to perform a cleanup.

In addition, upon reasonable notice, such person either (i) shall grant any such officer, employee, or representative access at all reasonable times to any vessel, facility, establishment, place, property, or location to inspect and copy all documents or records relating to such matters or (ii) shall copy and furnish to the officer, employee, or representative all such documents or records, at the option and expense of such person.

REFERENCES

26-29

DOE-LM/1599-2008

Data Validation Package

November 2007
Groundwater Sampling at the Ambrosia Lake, New Mexico, Disposal Site

March 2008

U.S. Department of Energy
Office of Legacy Management

Work Performed by the S.M. Stoller Corporation Under DOE Contract No. DE-AM01-07LM00060 for the U.S. Department of Energy Office of Legacy Management.

Contents

Groundwater Quality Data by Location (USEE100) FOR SITE AMB01, Ambrosia Lake Disposal Site
REPORT DATE: 2/22/2008
Location: 0675 WELL

Parameter	Units	Sample Date	Sample ID	Depth Range (Ft BLS)			Result	Qualifiers Lab	Qualifiers Data	Qualifiers QA	Detection Limit	Uncertainty
Alkalinity, Total (As CaCO3)	mg/L	11/07/2007	0001	21.81	-	31.81	139		F	#		
Molybdenum	mg/L	11/07/2007	0001	21.81	-	31.81	0.12		F	#	.00049	
Molybdenum	mg/L	11/07/2007	0002	21.81	-	31.81	0.12		F	#	.00049	
Nitrate + Nitrite as Nitrogen	mg/L	11/07/2007	0001	21.81	-	31.81	54		F	#	.5	
Nitrate + Nitrite as Nitrogen	mg/L	11/07/2007	0002	21.81	-	31.81	66		F	#	.5	
Oxidation Reduction Potential	mV	11/07/2007	N001	21.81	-	31.81	58.3		F	#		
pH	s.u.	11/07/2007	N001	21.81	-	31.81	7.51		F	#		
Selenium	mg/L	11/07/2007	0001	21.81	-	31.81	0.86		F	#	.0056	
Selenium	mg/L	11/07/2007	0002	21.81	-	31.81	0.82		F	#	.0056	
Specific Conductance	umhos /cm	11/07/2007	N001	21.81	-	31.81	5660		F	#		
Sulfate	mg/L	11/07/2007	0001	21.81	-	31.81	3200		F	#	25	
Sulfate	mg/L	11/07/2007	0002	21.81	-	31.81	3200		F	#	25	
Temperature	C	11/07/2007	N001	21.81	-	31.81	13.8		F	#		
Turbidity	NTU	11/07/2007	N001	21.81	-	31.81	1.39		F	#		
Uranium	mg/L	11/07/2007	0001	21.81	-	31.81	0.27		F	#	.000058	
Uranium	mg/L	11/07/2007	0002	21.81	-	31.81	0.27		F	#	.000058	

Groundwater Quality Data by Location (USEE100) FOR SITE AMB01, Ambrosia Lake Disposal Site
REPORT DATE: 2/22/2008
Location: 0678 WELL

Parameter	Units	Sample Date	Sample ID	Depth Range (Ft BLS)	Result	Qualifiers Lab	Qualifiers Data	Qualifiers QA	Detection Limit	Uncertainty
Molybdenum	mg/L	11/07/2007	0001	237.15 - 257.15	0.0057		F	#	.000098	
Nitrate + Nitrite as Nitrogen	mg/L	11/07/2007	0001	237.15 - 257.15	390		F	#	5	
Oxidation Reduction Potential	mV	11/07/2007	N001	237.15 - 257.15	36.1		F	#		
pH	s.u.	11/07/2007	N001	237.15 - 257.15	7.24		F	#		
Selenium	mg/L	11/07/2007	0001	237.15 - 257.15	0.12		F	#	.00028	
Specific Conductance	umhos /cm	11/07/2007	N001	237.15 - 257.15	14318		F	#		
Sulfate	mg/L	11/07/2007	0001	237.15 - 257.15	8200		F	#	100	
Temperature	C	11/07/2007	N001	237.15 - 257.15	12.13		F	#		
Turbidity	NTU	11/07/2007	N001	237.15 - 257.15	1.62		F	#		
Uranium	mg/L	11/07/2007	0001	237.15 - 257.15	0.053		F	#	.000012	

SAMPLE ID CODES: 000X = Filtered sample (0.45 µm). N00X = Unfiltered sample. X = replicate number.

LAB QUALIFIERS:
- * Replicate analysis not within control limits.
- > Result above upper detection limit.
- A TIC is a suspected aldol-condensation product.
- B Inorganic: Result is between the IDL and CRDL. Organic: Analyte also found in method blank.
- C Pesticide result confirmed by GC-MS.
- D Analyte determined in diluted sample.
- E Inorganic: Estimate value because of interference, see case narrative. Organic: Analyte exceeded calibration range of the GC-MS.
- H Holding time expired, value suspect.
- I Increased detection limit due to required dilution.
- J Estimated
- N Inorganic or radiochemical: Spike sample recovery not within control limits. Organic: Tentatively identified compound (TIC).
- P > 25% difference in detected pesticide or Aroclor concentrations between 2 columns.
- U Analytical result below detection limit.
- W Post-digestion spike outside control limits while sample absorbance < 50% of analytical spike absorbance.
- X,Y,Z Laboratory defined qualifier, see case narrative.

STATIC WATER LEVELS (USEE700) FOR SITE AMB01, Ambrosia Lake Disposal Site
REPORT DATE: 2/22/2008

Location Code	Flow Code	Top of Casing Elevation (Ft)	Measurement Date	Measurement Time	Depth From Top of Casing (Ft)	Water Elevation (Ft)	Water Level Flag
0675	D	6966.65	11/07/2007		18.5	6948.15	
0678	C	6987.94	11/07/2007		225.55	6762.39	

FLOW CODES: B BACKGROUND C CROSS GRADIENT D DOWN GRADIENT F OFF SITE
N UNKNOWN O ON SITE U UPGRADIENT

WATER LEVEL FLAGS: D Dry F FLOWING

DOE-LM/GJ810-2005

Data Validation Package

September 2004 Ground Water Sampling at the Ambrosia Lake, New Mexico, Disposal Site

March 2005

U.S. Department of Energy
Office of Legacy Management

Work Performed by the S.M. Stoller Corporation under DOE Contract No. DE-AC01-02GJ79491 for the U.S. Department of Energy Office of Legacy Management.

Sampling Event Summary

Site: Ambrosia Lake, New Mexico, Disposal Site

Sampling Period: September 21, 2004

The *Long-Term Surveillance Plan for the Ambrosia Lake, New Mexico, Disposal Site* does not require ground water monitoring because of the application of supplemental standards. However, at the request of the New Mexico Environment Department, the U.S. Department of Energy conducts limited monitoring at two locations, monitor wells 0675 and 0678. Water levels were measured at each sampled well.

Sampling and analysis was conducted as specified in *FY 2004 Sampling Frequencies and Analyses* (January 2004). The data from this sampling event are consistent with values previously obtained.

Richard K. Johnson
Site Lead

3/21/05
Date

Contents

Data Assessment Summary

Water Sampling Field Activities Verification Checklist

Project	Ambrosia Lake, New Mexico	**Date(s) of Water Sampling**	September 21, 2004
Date(s) of Verification	January 27, 2005	**Name of Verifier**	Steve Donivan

	Response (Yes, No, NA)	Comments
1. Is the SAP the primary document directing field procedures?	Yes	
List other documents, SOP's, instructions.		Work order dated 4/6/2004
2. Were the sampling locations specified in the planning documents sampled?	Yes	
3. Was a pre-trip calibration conducted as specified in the above named documents?	Yes	
4. Was an operational check of the field equipment conducted twice daily?	No	One operational check, samples collected within a 4 hour period
Did the operational checks meet criteria?	Yes	
5. Were the number and types (alkalinity, temperature, Ec, pH, turbidity, DO, ORP) of field measurements taken as specified?	Yes	
6. Was the Category of the well documented?	No	Well 0675 not categorized, assumed to be category I
7. Were the following conditions met when purging a Category I well:		
Was one pump/tubing volume purged prior to sampling?	Yes	
Did the water level stabilize prior to sampling?	Yes	
Did pH, specific conductance, and turbidity measurements stabilize prior to sampling?	Yes	
Was the flow rate less than 500 mL/min?	Yes	
If a portable pump was used, was there a 4 hour delay between pump installation and sampling?	NA	

Water Sampling Field Activities Verification Checklist (continued)

	Response (Yes, No, NA)	Comments
8. Were the following conditions met when purging a Category II well:		
Was the flow rate less than 500 mL/min?	Yes	
Was one pump/tubing volume removed prior to sampling?	Yes	
9. Were duplicates taken at a frequency of one per 20 samples?	Yes	
10. Were equipment blanks taken at a frequency of one per 20 samples that were collected with nondedicated equipment?	NA	
11. Were trip blanks prepared and included with each shipment of VOC samples?	NA	
12. Were QC samples assigned a fictitious site identification number?	Yes	
Was the true identity of the samples recorded on the Quality Assurance Sample Log?	Yes	
13. Were samples collected in the containers specified?	Yes	
14. Were samples filtered and preserved as specified?	Yes	
15. Were the number and types of samples collected as specified?	Yes	
16. Were chain of custody records completed and was sample custody maintained?	Yes	
17. Are field data sheets signed and dated by both team members?	No	One signature
18. Was all other pertinent information documented on the field data sheets?	Yes	
19. Was the presence or absence of ice in the cooler documented at every sample location?	Yes	
20. Were water levels measured at the locations specified in the planning documents?	Yes	

Attachment 2
Data Presentation

Ground Water Quality Data

Ground Water Quality Data by Location (USEE100) FOR SITE AMB01, Ambrosia Lake Disposal Site
REPORT DATE: 3/14/2005
Location: 0675 (well)

Parameter	Units	Sample Date	Sample ID	Depth Range (Ft BLS)	Result	Qualifiers Lab	Qualifiers Data	Qualifiers QA	Detection Limit	Uncertainty
Alkalinity, Total (As CaCO3)	mg/L	9/21/2004	0001	21.81 - 31.81	315		F	#		
Molybdenum	mg/L	9/21/2004	0001	21.81 - 31.81	0.6		JF	#	0.0034	
Molybdenum	mg/L	9/21/2004	0002	21.81 - 31.81	0.56		JF	#	0.0034	
Nitrate + Nitrite as Nitrogen	mg/L	9/21/2004	0001	21.81 - 31.81	50		JF	#	0.5	
Nitrate + Nitrite as Nitrogen	mg/L	9/21/2004	0002	21.81 - 31.81	50		JF	#	0.5	
Oxidation Reduction Potential	mV	9/21/2004	N001	21.81 - 31.81	60.5		F	#		
pH	s.u.	9/21/2004	N001	21.81 - 31.81	7.02		F	#		
Selenium	mg/L	9/21/2004	0001	21.81 - 31.81	0.66		F	#	0.0015	
Selenium	mg/L	9/21/2004	0002	21.81 - 31.81	0.65		F	#	0.0015	
Specific Conductance	umhos /cm	9/21/2004	N001	21.81 - 31.81	6555		F	#		
Sulfate	mg/L	9/21/2004	0001	21.81 - 31.81	3200		F	#	50	
Sulfate	mg/L	9/21/2004	0002	21.81 - 31.81	3200		F	#	50	
Temperature	C	9/21/2004	N001	21.81 - 31.81	13.89		F	#		
Turbidity	NTU	9/21/2004	N001	21.81 - 31.81	4.85		F	#		
Uranium	mg/L	9/21/2004	0001	21.81 - 31.81	1.1		F	#	0.00017	
Uranium	mg/L	9/21/2004	0002	21.81 - 31.81	1.1		F	#	0.00017	

Ground Water Quality Data by Location (USEE100) FOR SITE AMB01, Ambrosia Lake Disposal Site
REPORT DATE: 3/14/2005
Location: 0678 (well)

Parameter	Units	Sample Date	Sample ID	Depth Range (Ft BLS)		Result	Qualifiers Lab	Qualifiers Data	Qualifiers QA	Detection Limit	Uncertainty
Alkalinity, Total (As CaCO3)	mg/L	9/21/2004	0001	237.15 -	257.15	639		FQ	#		
Molybdenum	mg/L	9/21/2004	0001	237.15 -	257.15	0.012		JFQ	#	0.00017	
Nitrate + Nitrite as Nitrogen	mg/L	9/21/2004	0001	237.15 -	257.15	520		JFQ	#	5	
Oxidation Reduction Potential	mV	9/21/2004	N001	237.15 -	257.15	63		FQ	#		
pH	s.u.	9/21/2004	N001	237.15 -	257.15	7.29		FQ	#		
Selenium	mg/L	9/21/2004	0001	237.15 -	257.15	0.23		FQ	#	0.0015	
Specific Conductance	umhos /cm	9/21/2004	N001	237.15 -	257.15	13580		FQ	#		
Sulfate	mg/L	9/21/2004	0001	237.15 -	257.15	6800		FQ	#	100	
Temperature	C	9/21/2004	N001	237.15 -	257.15	15.01		FQ	#		
Turbidity	NTU	9/21/2004	N001	237.15 -	257.15	14.6		FQ	#		
Uranium	mg/L	9/21/2004	0001	237.15 -	257.15	0.057		FQ	#	0.0000083	

SAMPLE ID CODES: 000X = Filtered sample (0.45 µm). N00X = Unfiltered sample. X = replicate number.
LAB QUALIFIERS:
- * Replicate analysis not within control limits.
- > Result above upper detection limit.
- A TIC is a suspected aldol-condensation product.
- B Inorganic: Result is between the IDL and CRDL. Organic: Analyte also found in method blank.
- C Pesticide result confirmed by GC-MS.
- D Analyte determined in diluted sample.
- E Inorganic: Estimate value because of interference, see case narrative. Organic: Analyte exceeded calibration range of the GC-MS.
- H Holding time expired, value suspect.
- I Increased detection limit due to required dilution.
- J Estimated
- N Inorganic or radiochemical: Spike sample recovery not within control limits. Organic: Tentatively identified compund (TIC).
- P > 25% difference in detected pesticide or Aroclor concentrations between 2 columns.
- U Analytical result below detection limit.
- W Post-digestion spike outside control limits while sample absorbance < 50% of analytical spike absorbance.
- X Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Y Laboratory defined (USEPA CLP organic) qualifier, see case narrative.
- Z Laboratory defined (USEPA CLP organic) qualifier, see case narrative.

DATA QUALIFIERS:
- F Low flow sampling method used. G Possible grout contamination, pH > 9. J Estimated value.
- L Less than 3 bore volumes purged prior to sampling. Q Qualitative result due to sampling technique R Unusable result.
- U Parameter analyzed for but was not detected. X Location is undefined.

QA QUALIFIER: # = validated according to Quality Assurance guidelines.

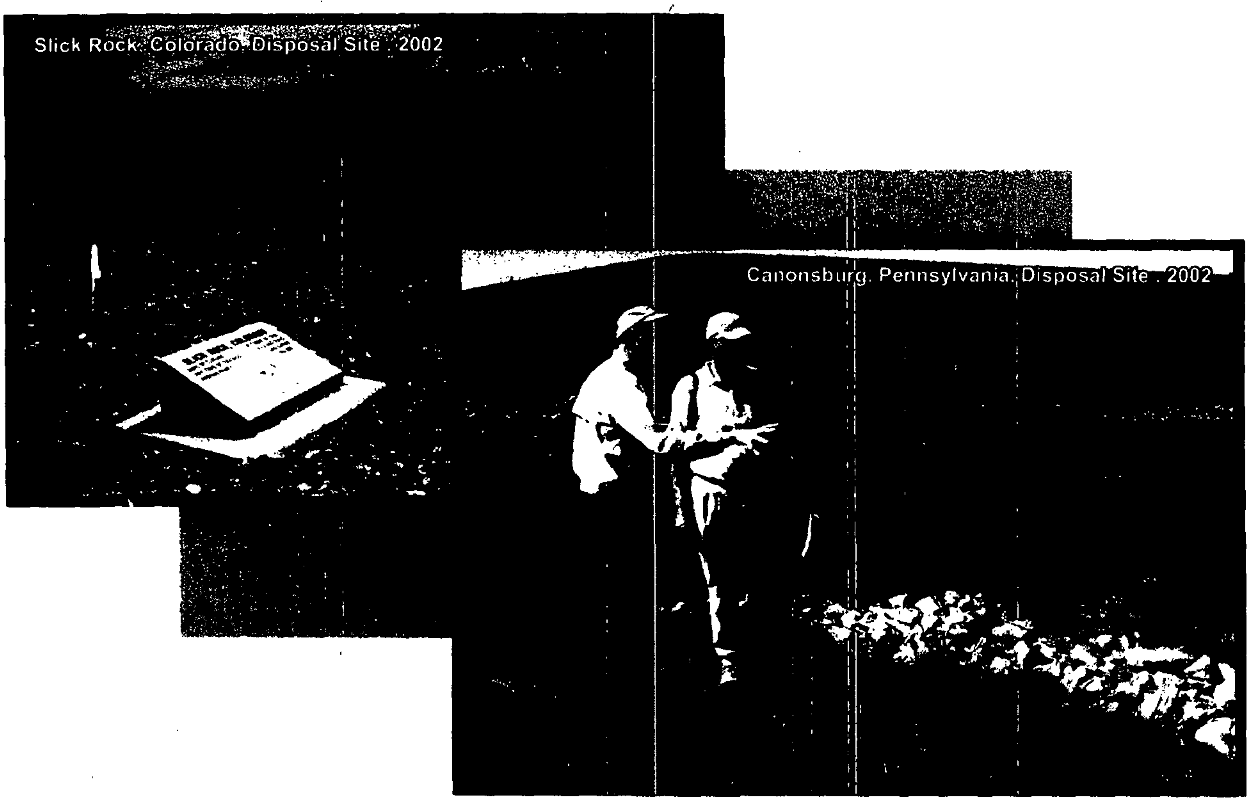
Equipment Blank Data

GJO–2002–392–TAC
GJO–LREP 6.3.1–5

Long-Term Surveillance and Maintenance Program

2002 Annual Site Inspection and Monitoring Report for Uranium Mill Tailings Radiation Control Act Title I Disposal Sites

December 2002



Work Performed Under DOE Contract No. DE–AC13–02GJ79491 for the U.S. Department of Energy

U.S. Department of Energy
Grand Junction Office
2597 B¾ Road
Grand Junction, CO 81503

WM-39

DEC 1 1 2002

Daniel M. Gillen
U.S. Nuclear Regulatory Commission
Fuel Cycle Facilities Branch, NMSS
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2747

Subject: *2002 Annual Site Inspection and Monitoring Report for UMTRCA Title I Disposal Sites*

Dear Mr. Gillen:

Four copies of the *2002 Annual Inspection and Monitoring Report for Uranium Mill Tailings Radiation Control Act Title I Disposal Sites* are enclosed. This report is submitted to comply with reporting requirements of 10 CFR 40.27.

The report covers the annual inspections of the 18 licensed Title I disposal sites and the closed portion of the unlicensed Grand Junction, Colorado, disposal site.

If NRC has comments or questions about this report, please contact me at 970/248-6027.

Sincerely,

John P. Gilmore

John P. Gilmore
Project Manager

Enclosure

cc w/o enclosure:
A. Kleinrath, DOE-GJO
R. Johnson, Stoller
Project File LREP 6.3.1 (thru A. Temple)

Gilmore/2002 Title I Report to NRC1.doc

NMSS08

GJO–2002–392–TAC
GJO–LREP 6.3.1–5

Long-Term Surveillance and Maintenance Program

2002 Annual Site Inspection and Monitoring Report for Uranium Mill Tailings Radiation Control Act Title I Disposal Sites

December 2002

Prepared for
U.S. Department of Energy
Idaho Operations Office
Grand Junction, Colorado

Work Performed Under DOE Contract Number DE–AC13–02GJ79491
Task Order Number ST03–102

S00831

Table of Contents

Acronyms

BLM	U.S. Bureau of Land Management
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GJO	Grand Junction Office
MCL	maximum concentration limit
mg/L	milligrams per liter
NRC	U.S. Nuclear Regulatory Commission
PCB	polychlorinated biphenyls
pCi/L	picocuries per liter
PL	Photo Location
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action [Project]
UMTRCA	Uranium Mill Tailings Radiation Control Act of 1978 (88 USC 7901, *et seq.*)

Executive Summary

This report, in fulfillment of a license requirement, presents the results of Long-Term Surveillance and Maintenance Program stewardship activities conducted by the U.S. Department of Energy (DOE) in 2002 at 19 uranium mill tailings disposal sites established under Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978[1]. These activities verified that the UMTRCA Title I disposal sites remain in compliance with license requirements.

DOE operates 18 UMTRCA Title I sites under a general license granted by the U.S. Nuclear Regulatory Commission in accordance with Title 10 *Code of Federal Regulations* Part 40.27. The Grand Junction, Colorado, disposal site, included in the list of 19 Title I sites, will not be licensed until an open, operating portion of the cell is filled and closed, perhaps in 2023. This site is inspected in accordance with an interim Long-Term Surveillance Plan.

The Long-Term Surveillance and Maintenance Program at the DOE Grand Junction, Colorado, Office is responsible for providing stewardship services for these disposal sites. Services include site inspections and maintenance, monitoring of environmental media and institutional controls, conducting any necessary corrective action, and performing administrative, records, stakeholder participation, and other regulatory functions.

Annual site inspections and monitoring are conducted in accordance with site-specific Long-Term Surveillance Plans and procedures established by DOE to comply with license requirements. Each site inspection is performed to verify the integrity of visible features at the site; to identify changes or new conditions that may affect the long-term performance of the site; and to determine the need, if any, for maintenance, follow-up or contingency inspections, or corrective action. Program plans and site compliance reports are available on the Internet at **www.gjo.doe.gov**.

Many of the sites require routine maintenance including vegetation control, fence repairs, and sign replacement. The following nonroutine activities[2] occurred in 2002:

- Burrell, Pennsylvania—regulator concurred with revised Long-Term Surveillance Plan;
- Maybell, Colorado—placed additional riprap for erosion control, and installed boundary monuments at all property corners;
- Mexican Hat, Utah—revised the monitoring frequency for ground water seeps, and conducted a follow-up inspection to assess storm damage;
- Naturita, Colorado—closed the storm water discharge permit;
- Rifle, Colorado—installed a new fence and gate across the site access road; and
- Decommissioned 41 unneeded monitor wells and standpipes at five sites.

---

[1] Congress directed that the Moab, Utah, processing site be remediated under Title I of UMTRCA; this eventually will become the twentieth Title I disposal site.

[2] Nonroutine activities are defined in the *Long-Term Surveillance and Maintenance Program Plan*, (GJO-99-93-TAR, June 1999) as activities implemented in response to changes in site conditions, regulatory setting, or management structure following a regulatory compliance review.

Results of the annual site inspection and monitoring activities performed by the Long-Term Surveillance and Maintenance Program are reported in the site-specific chapters that follow. Significant actions and issues at each site are summarized in the following table, which includes an index number for each item that can be found in the left margin next to the corresponding text in the respective site chapter.

2002 Summary of UMTRCA Title I Site Issues and Status

Site	Chapter	Page	Index No.	Actions and Issues
Ambrosia Lake, New Mexico	1	1–2	1A	Shallow depression on disposal cell top.
		1–2	1B	Control of vegetation on cell top.
		1–5	1C	Control of vegetation along cell apron.
		1–5	1D	Ground water monitoring.
Burrell, Pennsylvania	2	2–1	2A	U.S. Nuclear Regulatory Commission concurrence with revised Long-Term Surveillance Plan.
		2–2	2B	Obtain regulator concurrence to remove derelict access gate.
				Maintenance: damaged perimeter signs replaced.
		2–2	2C	Maintenance: missing boundary monument cap replaced.
		2–5	2D	Unneeded monitor wells decommissioned.
		2–5	2E	
Canonsburg, Pennsylvania	3	3–2	3A	Maintenance: missing perimeter sign replaced.
		3–2	3B	Unneeded monitor wells decommissioned.
		3–5	3C	Institutional controls needed for sale of Area C.
		3–6	3D	Ground water monitoring.
Durango, Colorado	4	4–2	4A	Maintenance: missing perimeter signs replaced and reinforced.
		4–2	4B	Maintenance: vegetation control.
		4–2	4C	Maintenance: biological control of vegetation initiated.
		4–6	4D	Ground water monitoring: existing well added to monitoring network.
Falls City, Texas	5	5–2	5A	Maintenance: vegetation control.
		5–5	5B	Ground water monitoring.
Grand Junction, Colorado	6	6–2	6A	Maintenance: erosion along access road.
		6–2	6B	Maintenance: perimeter signs resecured or replaced.
		6–5	6C	Vegetation encroachment and evaluation.
		6–5	6D	Maintenance: erosion of drainage ditch.
		6–10	6E	Ground water monitoring.
Green River, Utah	7	7–2	7A	Maintenance: missing perimeter signs replaced.
		7–5	7B	Maintenance: access gate resecured.
		7–6	7C	Ground water monitoring.
		7–7	7D	Precipitation monitoring.
Gunnison, Colorado	8	8–2	8A	Maintenance: missing perimeter sign replaced.
		8–2	8B	Maintenance: vegetation control.
		8–5	8C	Inspected condition of riprap in test areas.
Lakeview, Oregon	9	9–1	9A	Revised Long-Term Surveillance Plan pending NRC concurrence.
		9–2	9B	Maintenance: fence repaired.
		9–2	9C	Maintenance: entrance sign replaced.
		9–2	9D	Investigation on effects of vegetation on cell.
		9–5	9E	Riprap size recalculated for gradation tests.
Lowman, Idaho	10	10–2	10A	Vegetation encroachment.
		10–5	10B	Control of noxious weeds.
		10–6	10C	Revised Long-Term Surveillance Plan in preparation.
Maybell, Colorado	11	11–2	11A	Maintenance: fence repaired.
		11–2	11B	Perimeter sign locations verified.
		11–2	11C	Boundary monuments installed.
		11–5	11D	Unneeded monitor wells decommissioned.
		11–5	11E	Maintenance: vegetation control.
		11–5	11F	Additional riprap placed for erosion control.
		11–7	11G	Settlement plates resurveyed.
Mexican Hat, Utah	12	12–2	12A	Storm runoff damage.
		12–5	12B	Follow-up inspection to assess storm damage.
		12–5	12C	Seep monitoring: revised sampling requirement.

Site	Chapter	Page	Index No.	Actions and Issues
Naturita, Colorado	13	13–2	13A	Standpipe decommissioned.
		13–5	13B	Revision of toe drain right-of-way permits pending.
		13–5	13C	Storm water discharge permit closed.
		13–5	13D	Maintenance: vegetation control.
		13–6	13E	Ground water monitoring.
Rifle, Colorado	14	14–2	14A	Security: fence and gate installed across access road.
		14–2	14B	Maintenance: cell-dewatering pump and wellhead repaired.
		14–6	14C	New erosion near cell.
		14–6	14D	Reclamation: BLM Temporary Permit active until successful revegetation.
Salt Lake City, Utah	15	15–2	15A	New access route.
		15–2	15B	New entrance gate and relocated entrance sign.
Shiprock, New Mexico	16	16–2	16A	Erosion and fence damage from storm runoff.
		16–2	16B	Boundary monument washed away.
		16–5	16C	Vegetation encroachment.
		16–5	16D	Erosion below armored portion of outfall channel.
Slick Rock, Colorado	17	17–2	17A	Maintenance: fence repaired.
		17–2	17B	Two standpipes decommissioned.
		17–5	17C	Maintenance: vegetation control.
Spook, Wyoming	18	18–5	18A	Agreement executed between DOE and adjacent landowner concerning use of water well.
Tuba City, Arizona	19	19–2	19A	Active ground water remediation activities.
		19–5	19B	Maintenance: vegetation control.
		19–5	19C	On-going evaluation of sand accumulation and vegetation encroachment on cell.
		19–5	19D	Sand and tumbleweed accumulation along fence.
		19–6	19E	Ground water monitoring.

End of current text

2002 Annual Compliance Report
Ambrosia Lake, New Mexico, Disposal Site

Compliance Summary

The site, inspected on May 8, 2002, was in excellent condition. Several perimeter signs were realigned and resecured. Deep-rooted vegetation was observed on and around the cell cover and will be removed. DOE conducted the first post-closure ground water sampling event for the site. Inspectors identified no requirement for a follow-up or contingency inspection.

Compliance Requirements

Requirements for the long-term surveillance and maintenance of the Ambrosia Lake, New Mexico, Uranium Mill Tailings Radiation Control Act (UMTRCA) Title I disposal site are specified in the *Long-Term Surveillance Plan for the Ambrosia Lake, New Mexico, Disposal Site* (DOE/AL/62350–211, Rev. 1, U.S. Department of Energy [DOE], Albuquerque Operations Office, July 1996) and in procedures established by the DOE Grand Junction Office to comply with requirements of Title 10 *Code of Federal Regulations* Part 40.27 (10 CFR 40.27). Table 1–1 lists these requirements.

Table 1–1. License Requirements for the Ambrosia Lake, New Mexico, Disposal Site

Requirement	Long-Term Surveillance Plan	This Report
Annual Inspection and Report	Section 6.0	Section 1.0
Follow-up or Contingency Inspections	Sections 6.0 and 7.0	Section 2.0
Routine Maintenance and Repairs	Section 8.0	Section 3.0
Ground Water Monitoring	Section 5.0	Section 4.0
Corrective Action	Section 9.0	Section 5.0

Compliance Review

1.0 Annual Inspection and Report

The site, north of Grants, New Mexico, was inspected on May 8, 2002. Results of the inspection are described below. Features mentioned in this report are shown on Figure 1–1. Numbers in the left margin of this report refer to items summarized in the Executive Summary table.

1.1 Specific Site Surveillance Features

Access Road, Entrance Sign, Perimeter Signs—The Ambrosia Lake Disposal Site is accessed via a gravel road that leads to the site (and beyond) from New Mexico State Highway 509. The site is reached by passing through a locked gate and traveling east along this road for approximately 1 mile. The gate is locked because the road leads to private mining and grazing interests that lie farther to the east. Numerous locks are connected in series to allow other users passage through the gate. The access road passes through the DOE-owned property along the south boundary of the site.

The entrance and all perimeter signs were in good condition. Several perimeter signs along the western property boundary had rotated on their posts; the movement most likely caused by prevailing winds. Inspectors realigned the signs to their proper position and resecured the associated hardware. Future inspections will continue to monitor the condition of the signs.

Site Markers, Survey and Boundary Monuments—The two granite site markers, three combined survey and boundary monuments, and five additional boundary monuments were all undisturbed and in excellent condition.

Monitor Wells—Twenty monitor wells were decommissioned in September 2001. All decommissioned monitor well sites were reclaimed at the time of decommissioning. There is little to no evidence of land disturbance associated with these reclaimed sites, and the vegetation, although sparse, is expected to be restored to a condition representative of the surrounding, undisturbed areas. There is no further need to inspect these decommissioned sites during future inspections.

Only two monitor wells (0675 and 0678) remain at this site. Both wells were inspected and found to be secure and in excellent condition.

Mine Vents—Two mine vent shafts, associated with abandoned underground mines, are within the site boundary; a third vent is west of the site within DOE's restrictive easement that prohibits mining. The mine vent located north of the disposal cell is the only one that has a spot-welded cover that can be considered a permanent closure. The other two vents have bolted-on covers that do not constitute a permanent closure. All vents were secure at the time of the inspection.

1.2 Transects

To ensure a thorough and efficient inspection, the site was divided into four areas referred to as transects: (1) the riprap-covered top of the disposal cell; (2) the riprap-covered side slopes and apron of the cell; (3) the graded and revegetated area between the disposal cell and the site perimeter; and (4) the outlying area.

Top of Disposal Cell—The top of the disposal cell was in excellent condition. With exception of one location there was no evidence of cracking, settling, slumping, or erosion. A shallow
1A depression around settlement plate SP–4 was first noted during the 1997 inspection; however, there has been no visible indication to suggest the depression holds water. At the time of the 2002 annual inspection, the subsidence was estimated to measure approximately 20 feet across and approximately 1 foot in depth. The depression will continue to be monitored to ensure the integrity of the cell cover.

1B Several isolated four-wing saltbush shrubs were observed at various locations on the cell cover. These deep-rooted shrubs growing on the disposal cell will be removed before the next inspection.

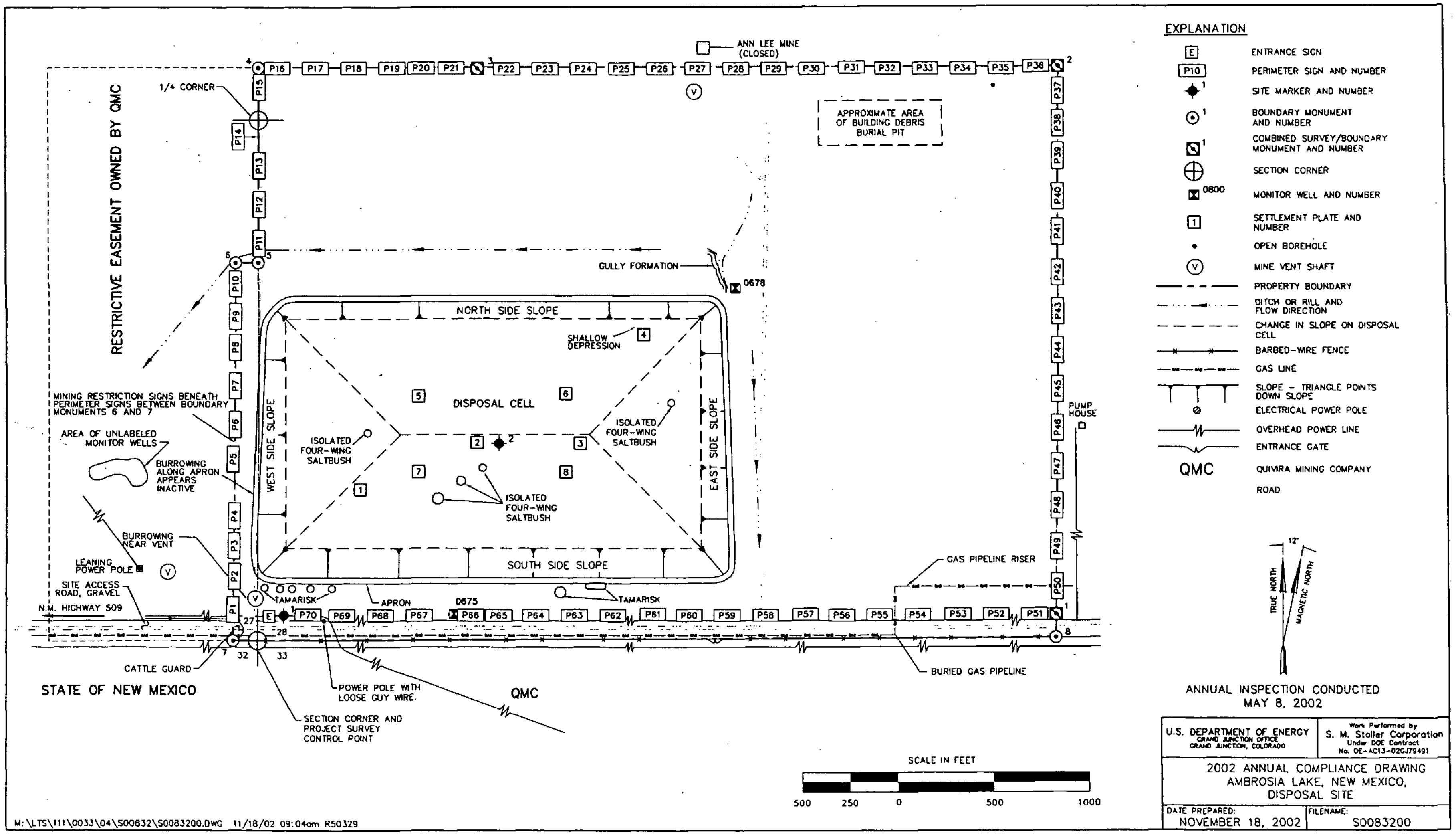


Figure 1-1. 2002 Annual Compliance Drawing for the Ambrosia Lake, New Mexico, Disposal Site

Side Slopes and Apron—The side slopes and apron were in excellent condition and showed no evidence of cracking, settling, slumping, or erosion. Tamarisk was observed growing in several
1C locations along the southern edge of the disposal cell apron and will be removed before the next inspection. No evidence of recent animal burrowing was noted during this year's inspection. No standing water was observed in the apron along the south side slope, as had been noted during previous inspections.

Graded and Revegetated Site Area—In general, site vegetation was healthier than vegetation in the surrounding areas. Some areas were windswept with little growth, while other areas had excellent coverage. Inspectors observed little evidence of cattle grazing adjacent to the disposal cell and the outlying portions of the DOE property. To date, grazing in the revegetated areas of the site has not been a problem. The perennial grasses planted in the graded areas adjacent to the disposal cell are well established.

For several years, inspectors have monitored rills and gullies within the DOE property north and east of the disposal cell. The gullies are located at sufficient distances from the disposal cell that they do not present an immediate threat to the cell. The gullies appeared to be stabilizing..

Outlying Area—The area within 0.25 mile of the site boundary was inspected and found to be unchanged.

2.0 Follow-up or Contingency Inspections

No follow-up or contingency inspections were required in 2002.

3.0 Routine Maintenance and Repairs

Other than realigning several perimeter signs, no maintenance or repairs were required in 2002.

4.0 Ground Water Monitoring

The Long-Term Surveillance Plan establishes that ground water monitoring is not required at this site because (1) the ground water is heavily contaminated from underground uranium mining and naturally occurring mineralization, and (2) the uppermost aquifer is of limited use due to low yield. However, at the request of the New Mexico Environment Department, DOE conducts limited monitoring at two locations. Monitor well 0675 is completed in the alluvium, and monitor well 0678 is completed in the uppermost sandstone bed. DOE samples these locations once every third year, for up to 30 years, and evaluates the results after every third sampling event.

1D The first post-closure sampling event was conducted on December 7, 2001. The data from this sampling event are presented in Table 1–2.

Table 1–2. Analytical Results from the December 7, 2001, Sampling Event

Well	pH	Electrical Conductivity µOhms/cm	Uranium mg/L	Molybdenum mg/L	Selenium mg/L	Nitrate (as N) mg/L	Sulfate mg/L
0675	6.72	7,000	3.17	3.92	0.433	41.7	4,040
0678	7.26	14,280	0.073	0.023	0.169	479	7,340

µOhms/cm = micro-ohms per centimeter
mg/L = milligrams per liter

5.0 Corrective Action

Corrective action is action taken to correct out-of-compliance or hazardous conditions that create a potential health and safety problem or that may affect the integrity of the disposal cell or compliance with 40 CFR 192.

No corrective action was required in 2002.

20.6.2.7WW

20.6.2 NMAC

NEW MEXICO
WATER QUALITY CONTROL COMMISSION
REGULATIONS

Effective July 16, 2006

New Mexico Water Quality Control Commission
1190 St. Francis Drive
P.O. Box 26110
Santa Fe, NM 87502

TITLE 20 ENVIRONMENTAL PROTECTION
CHAPTER 6 WATER QUALITY
PART 2 GROUND AND SURFACE WATER PROTECTION

20.6.2.1 ISSUING AGENCY: Water Quality Control Commission
[12-1-95; 20.6.2.1 NMAC - Rn, 20 NMAC 6.2.I.1000, 1-15-01]

20.6.2.2 SCOPE: All persons subject to the Water Quality Act, NMSA 1978, Sections 74-6-1 et seq.
[12-1-95; 20.6.2.2 NMAC - Rn, 20 NMAC 6.2.I.1001, 1-15-01]

20.6.2.3 STATUTORY AUTHORITY: Standards and Regulations are adopted by the commission under the authority of the Water Quality Act, NMSA 1978, Sections 74-6-1 through 74-6-17.
[2-18-77, 9-20-82, 12-1-95; 20.6.2.3 NMAC - Rn, 20 NMAC 6.2.I.1002, 1-15-01]

20.6.2.4 DURATION: Permanent.
[12-1-95; 20.6.2.4 NMAC - Rn, 20 NMAC 6.2.I.1003, 1-15-01]

20.6.2.5 EFFECTIVE DATE: December 1, 1995 unless a later date is cited at the end of a section.
[12-1-95, 11-15-96; 20.6.2.5 NMAC - Rn, 20 NMAC 6.2.I.1004, 1-15-01; A, 1-15-01]

20.6.2.6 OBJECTIVE: The objective of this Part is to implement the Water Quality Act, NMSA 1978, Sections 74-6-1 et seq.
[12-1-95; 20.6.2.6 NMAC - Rn, 20 NMAC 6.2.I.1005, 1-15-01]

20.6.2.7 DEFINITIONS: Terms defined in the Water Quality Act, but not defined in this part, will have the meaning given in the act. As used in this part:

A. **"abandoned well"** means a well whose use has been permanently discontinued or which is in a state of disrepair such that it cannot be rehabilitated for its intended purpose or other purposes including monitoring and observation;

B. **"abate" or "abatement"** means the investigation, containment, removal or other mitigation of water pollution;

C. **"abatement plan"** means a description of any operational, monitoring, contingency and closure requirements and conditions for prevention, investigation and abatement of water pollution, and includes Stage 1, Stage 2, or Stage 1 and 2 of the abatement plan, as approved by the secretary;

D. **"adjacent properties"** means properties that are contiguous to the discharge site or property that would be contiguous to the discharge site but for being separated by a public or private right of way, including roads and highways.

E. **"background"** means, for purposes of ground-water abatement plans only and for no other purposes in this part or any other regulations including but not limited to surface-water standards, the amount of ground-water contaminants naturally occurring from undisturbed geologic sources or water contaminants which the responsible person establishes are occurring from a source other than the responsible person's facility; this definition shall not prevent the secretary from requiring abatement of commingled plumes of pollution, shall not prevent responsible persons from seeking contribution or other legal or equitable relief from other persons, and shall not preclude the secretary from exercising enforcement authority under any applicable statute, regulation or common law;

F. **"casing"** means pipe or tubing of appropriate material, diameter and weight used to support the sides of a well hole and thus prevent the walls from caving, to prevent loss of drilling mud into porous ground, or to prevent fluid from entering or leaving the well other than to or from the injection zone;

G. **"cementing"** means the operation whereby a cementing slurry is pumped into a drilled hole and/or forced behind the casing;

H. **"cesspool"** means a **"drywell"** that receives untreated domestic liquid waste containing human excreta, and which sometimes has an open bottom and/or perforated sides; a large capacity cesspool means a cesspool that receives greater than 2,000 gallons per day of untreated domestic liquid waste;

I. **"collapse"** means the structural failure of overlying materials caused by removal of underlying materials;

J. **"commission"** means:

(1) the New Mexico water quality control commission or

(2) the department, when used in connection with any administrative and enforcement activity;

K. **"confining zone"** means a geological formation, group of formations, or part of a formation that is capable of limiting fluid movement from an injection zone;

L. **"conventional mining"** means the production of minerals from an open pit or underground excavation; underground excavations include mine shafts, workings and air vents, but does not include excavations primarily caused by in situ extraction activities;

M. **"daily composite sample"** means a sample collected over any twenty-four hour period at intervals not to exceed one hour and obtained by combining equal volumes of the effluent collected, or means a sample collected in accordance with federal permit conditions where a permit has been issued under the national pollutant discharge elimination system or for those facilities which include a waste stabilization pond in the treatment process where the retention time is greater than twenty (20) days, means a sample obtained by compositing equal volumes of at least two grab samples collected within a period of not more than twenty-four (24) hours;

N. **"department", "agency",** or **"division"** means the New Mexico environment department or a constituent agency designated by the commission;

O. **"discharge permit"** means a discharge plan approved by the department;

P. **"discharge permit modification"** means a change to the requirements of a discharge permit that result from a change in the location of the discharge, a significant increase in the quantity of the discharge, a significant change in the quality of the discharge; or as r[illegible]ed by the secretary;

Q. **"discharge permit renewal"** means the re-issuance of a discharge permit for the same, previously permitted discharge;

R. **"discharge plan"** means a description of any operational, monitoring , contingency, and closure requirements and conditions for any discharge of effluent or leachate which may move directly or indirectly into ground water;

S. **"discharge site"** means the entire site where the discharge and associated activities will take place;

T. **"disposal"** means to abandon, deposit, inter or otherwise discard a fluid as a final action after its use has been achieved;

U. **"domestic liquid waste"** means human excreta and water-carried waste from typical residential plumbing fixtures and activities, including but not limited to waste from toilets, sinks, bath fixtures, clothes or dishwashing machines and floor drains;

V. **"domestic liquid waste treatment unit"** means a watertight unit designed, constructed and installed to stabilize only domestic liquid waste and to retain solids contained in such domestic liquid waste, including but not limited to aerobic treatment units and septic tanks;

W. **"drywell"** means a well, other than an improved sinkhole or subsurface fluid distribution system, completed above the water table so that its bottom and sides are typically dry except when receiving fluids;

X. **"experimental technology"** means a technology which has not been proven feasible under the conditions in which it is being tested;

Y. **"fluid"** means material or substance which flows or moves whether in a semisolid, liquid, sludge, gas, or any other form or state;

Z. **"ground water"** means interstitial water which occurs in saturated earth material and which is capable of entering a well in sufficient amounts to be utilized as a water supply;

AA. **"hazard to public health"** exists when water which is used or is reasonably expected to be used in the future as a human drinking water supply exceeds at the time and place of such use, one or more of the numerical standards of Subsection A of 20.6.2.3103 NMAC, or the naturally occurring concentrations, whichever is higher, or if any toxic pollutant affecting human health is present in the water; in determining whether a discharge would cause a hazard to public health to exist, the secretary shall investigate and consider the purification and dilution reasonably expected to occur from the time and place of discharge to the time and place of withdrawal for use as human drinking water;

BB. **"improved sinkhole"** means a naturally occurring karst depression or other natural crevice found in volcanic terrain and other geologic settings which have been modified by man for the purpose of directing and emplacing fluids into the subsurface;

CC. **"injection"** means the subsurface emplacement of fluids through a well;

DD. **"injection zone"** means a geological formation, group of formations, or part of a formation receiving fluids through a [illegible];

EE. **"motor vehicle waste disposal well"** means a well which receives or has received fluids from vehicular repair or maintenance activities;

FF. **"non-aqueous phase liquid"** means an interstitial body of liquid oil, petroleum product, petrochemical, or organic solvent, including an emulsion containing such material;

GG. **"operational area"** means a geographic area defined in a project discharge permit where a group of wells or well fields in close proximity comprise a single class III well operation;

HH. **"owner of record"** means an owner of property according to the property records of the tax assessor in the county in which the discharge site is located at the time the application was deemed administratively complete;

II. **"packer"** means a device lowered into a well to produce a fluid-tight seal within the casing;

JJ. **"person"** means an individual or any other entity including partnerships, corporation, associations, responsible business or association agents or officers, the state or a political subdivision of the state or any agency, department or instrumentality of the United States and any of its officers, agents or employees;

KK. **"petitioner"** means a person seeking a variance from a regulation of the commission pursuant to Section 74-6-4(G) NMSA 1978;

LL. **"plugging"** means the act or process of stopping the flow of water, oil or gas into or out of a geological formation, group of formations or part of a formation through a borehole or well penetrating these geologic units;

MM. **"project discharge permit"** means a discharge permit which describes the operation of similar class III wells or well fields within one or more individual operational areas;

NN. **"refuse"** includes food, swill, carrion, slops and all substances from the preparation, cooking and consumption of food and from the handling, storage and sale of food products, the carcasses of animals, junked parts of automobiles and other machinery, paper, paper cartons, tree branches, yard trimmings, discarded furniture, cans, oil, ashes, bottles, and all unwholesome material;

OO. **"responsible person"** means a person who is required to submit an abatement plan or who submits an abatement plan pursuant to this part;

PP. **"secretary"** or **"director"** means the secretary of the New Mexico department of environment or the director of a constituent agency designated by the commission;

QQ. **"sewer system"** means pipelines, conduits, pumping stations, force mains, or other structures, devices, appurtenances or facilities used for collecting or conducting wastes to an ultimate point for treatment or disposal;

RR. **"sewerage system"** means a system for disposing of wastes, either by surface or underground methods, and includes se[illegible] systems, treatment works, disposal wells and other systems;

SS. **"significant modification of Stage 2 of the abatement plan"** means a change in the abatement technology used excluding design and operational parameters, or re-location of 25 percent or more of the compliance sampling stations, for any single medium, as designated pursuant to Paragraph (4) of Subsection E of 20.6.2.4106 NMAC;

TT. **"subsurface fluid distribution system"** means an assemblage of perforated pipes, drain tiles, or other mechanisms intended to distribute fluids below the surface of the ground;

UU. **"subsurface water"** means ground water and water in the vadose zone that may become ground water or surface water in the reasonably foreseeable future or may be utilized by vegetation;

VV. **"TDS"** means total dissolved solids as determined by the "calculation method" (sum of constituents), by the "residue on evaporation method at 180 degrees" of the "*U.S. geological survey techniques of water resource investigations*," or by conductivity, as the secretary may determine;

WW. **"toxic pollutant"** means a water contaminant or combination of water contaminants in concentration(s) which, upon exposure, ingestion, or assimilation either directly from the environment or indirectly by ingestion through food chains, will unreasonably threaten to injure human health, or the health of animals or plants which are commonly hatched, bred, cultivated or protected for use by man for food or economic benefit; as used in this definition injuries to health include death, histopathologic change, clinical symptoms of disease, behavioral abnormalities, genetic mutation, physiological malfunctions or physical deformations in such organisms or their offspring; in order to be considered a toxic pollutant a contaminant must be one or a combination of the potential toxic pollutants listed below and be at a concentration shown by scientific information currently available to the public to have potential for causing one or more of the effects listed above; any water contaminant or combination of the water contaminants in the list below creating a lifetime risk of more than one cancer per 100,000 exposed persons is a toxic pollutant:

(1) acrolein
(2) acrylonitrile
(3) aldrin
(4) benzene
(5) benzidine
(6) carbon tetrachloride
(7) chlordane
(8) chlorinated benzenes
  (a) monochlorobenzene
  (b) hexachlorobenzene
  (c) pentachlorobenzene
(9) 1,2,4,5-tetrachlorobenzene
(10) chlorinated ethanes
  (a) 1,2-dichloroethane
  (b) hexachloroethane
  (c) 1,1,2,2-tetrachloroethane
  (d) 1,1,1-trichloroethane
  (e) 1,1,2-trichloroethane
(11) chlorinated phenols
  (a) 2,4-dichlorophenol
  (b) 2,4,5-trichlorophenol
  (c) 2,4,6-trichlorophenol
(12) chloroalkyl ethers
  (a) bis (2-chloroethyl) ether
  (b) bis (2-chloroisopropyl) ether
  (c) bis (chloromethyl) ether
(13) chloroform
(14) DDT
(15) dichlorobenzene
(16) dichlorobenzidine
(17) 1,1-dichloroethylene
(18) dichloropropenes
(19) dieldrin
(20) diphenylhydrazine
(21) endosulfan
(22) endrin
(23) ethylbenzene
(24) halomethanes
  (a) bromodichloromethane
  (b) bromomethane
  (c) chloromethane
  (d) dichlorodifluoromethane
  (e) dichloromethane

(f) tribromomethane
(g) trichlorofluoromethane
(25) heptachlor
(26) hexachlorobutadiene
(27) hexachlorocyclohexane (HCH)
(a) alpha-HCH
(b) beta-HCH
(c) gamma-HCH
(d) technical HCH
(28) hexachlorocyclopentadiene
(29) high explosives (HE)
(a) 2,4-dinitrotoluene (2,4,DNT)
(b) 2,6-dinitrotoluene (2,6,DNT)
(c) octrahydro-1,3,5,7-tetranitro-1,3,5,7 tetrazocine (HMX)
(d) hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)
(e) 2,4,6-trinitrotoluene (TNT)
(30) isophorone
(31) methyl tertiary butyl ether
(32) nitrobenzene
(33) nitrophenols
(a) 2,4-dinitro-o-cresol
(b) dinitrophenols
(34) nitrosamines
(a) N-nitrosodiethylamine
(b) N-nitrosodimethylamine
(c) N-nitrosodibutylamine
(d) N-nitrosodiphenylamine
(e) N-nitrosopyrrolidine
(35) pentachlorophenol
(36) perchlorate
(37) phenol
(38) phthalate esters
(a) dibutyl phthalate
(b) di-2-ethylhexyl phthalate
(c) diethyl phthalate
(d) dimethyl phthalate
(39) polychlorinated biphenyls (PCB's)
(40) polynuclear aromatic hydrocarbons (PAH)
(a) anthracene
(b) 3,4-benzofluoranthene
(c) benzo (k) fluoranthene
(d) fluoranthene
(e) fluorene
(f) phenanthrene
(g) pyrene
(41) tetrachloroethylene
(42) toluene
(43) toxaphene
(44) trichloroethylene
(45) vinyl chloride
(46) xylenes
(a) o-xylene
(b) m-xylene
(c) p-xylene
(47) 1,1-dichloroethane
(48) ethylene dibromide (EDB)
(49) cis-1,2-dichloroethylene
(50) trans-1,2-dichloroethylene
(51) naphthalene
(52) 1-methylnaphthalene
(53) 2-methylnaphthalene

Wastewater published by the American Public Health Association or the most current edition of Methods for Chemical Analysis of Water and Wastes published by the Environmental Protection Agency, where applicable.

E. The following is a description of the Rio Grande Basin from the headwaters of Elephant Butte Reservoir to Angostura Diversion Dam as used in this Section. Begin at San Marcial USGS gauging station, which is the headwaters of Elephant Butte Reservoir Irrigation Project, thence northwest to U.S. Highway 60, nine miles ± west of Magdalena; thence west along the northeast edge of the San Agustin Plains closed basin; thence north along the east side of the north plains closed basin to the Continental Divide; thence northly along the Continental Divide to the community of Regina on State Highway 96; thence southeasterly along the crest of the San Pedro Mountains to Cerro Toledo Peak; thence southwesterly along the Sierra de Los Valles ridge and the Borrego Mesa to Bodega Butte; thence southerly to Angostura Diversion Dam which is the upper reach of the Rio Grande in this basin; thence southeast to the crest and the crest of the Manzano Mountains and the Los Pinos Mountains; thence southerly along the divide that contributes to the Rio Grande to San Marcial gauging station to the point and place of beginning; excluding all waters upstream of Jemez Pueblo which flow into the Jemez River drainage and the Bluewater Lake. Counties included in the basin are:

(1) north portion of Socorro County;
(2) northeast corner of Catron County;
(3) east portion of Valencia County;
(4) west portion of Bernalillo County;
(5) east portion of McKinley County; and
(6) most of Sandoval County.

[3-14-71, 9-3-72, 8-13-76, 2-20-81, 12-1-95; 20.6.2.2102 NMAC - Rn, 20 NMAC 6.2.II.2102, 1-15-01]

20.6.2.2103 - 20.6.2.2199: [RESERVED]
[12-1-95; 20.6.2.2103 - 20.6.2.2199 NMAC - Rn, 20 NMAC 6.2.II.2103-2199, 1-15-01]

20.6.2.2200 WATERCOURSE PROTECTION:
[12-1-95; 20.6.2.2200 NMAC - Rn, 20 NMAC 6.2.II.2200, 1-15-01]

20.6.2.2201 DISPOSAL OF REFUSE: No person shall dispose of any refuse in a natural watercourse or in a location and manner where there is a reasonable probability that the refuse will be moved into a natural watercourse by leaching or otherwise. Solids diverted from the stream and returned thereto are not subject to abatement under this Section.
[4-[illegible]8, 9-3-72; 20.6.2.2201 NMAC - Rn, 20 NMAC 6.2.II.2201, 1-15-01]

20.6.2.2202 - 20.6.2.2999: [RESERVED]
[12-1-95; 20.6.2.2202 - 20.6.2.2999 NMAC - Rn, 20 NMAC 6.2.II.2202-3100, 1-15-01]

20.6.2.3000 PERMITTING AND GROUND WATER STANDARDS:
[12-1-95; 20.6.2.3000 NMAC - Rn, 20 NMAC 6.2.III, 1-15-01]

20.6.2.3001 - 20.6.2.3100: [RESERVED]
[12-1-95; 20.6.2.3001 - 20.6.2.3100 NMAC - Rn, 20 NMAC 6.2.II.2202-3100, 1-15-01]

20.6.2.3101 PURPOSE:

A. The purpose of Sections 20.6.2.3000 through 20.6.2.3114 NMAC controlling discharges onto or below the surface of the ground is to protect all ground water of the state of New Mexico which has an existing concentration of 10,000 mg/l or less TDS, for present and potential future use as domestic and agricultural water supply, and to protect those segments of surface waters which are gaining because of ground water inflow, for uses designated in the New Mexico Water Quality Standards. Sections 20.6.2.3000 through 20.6.2.3114 NMAC are written so that in general:

(1) if the existing concentration of any water contaminant in ground water is in conformance with the standard of 20.6.2.3103 NMAC, degradation of the ground water up to the limit of the standard will be allowed; and

(2) if the existing concentration of any water contaminant in ground water exceeds the standard of Section 20.6.2.3103 NMAC, no degradation of the ground water beyond the existing concentration will be allowed.

B. Ground water standards are numbers that represent the pH range and maximum concentrations of water contaminants in the ground water which still allow for the present and future use of ground water resources.

C. The standards are not intended as maximum ranges and concentrations for use, and nothing herein contained shall be construed as limiting the use of waters containing higher ranges and concentrations.

[2-18-77; 20.6.2.3101 NMAC - Rn, 20 NMAC 6.2.III.3101, 1-15-01]

20.6.2.3102: [RESERVED]
[12-1-95; 20.6.2.3102 NMAC - Rn, 20 NMAC 6.2.III.3102, 1-15-01]

20.6.2.3103 STANDARDS FOR GROUND WATER OF 10,000 mg/l TDS CONCENTRATION OR LESS: The following standards are the allowable pH range and the maximum allowable concentration in ground water for the contaminants specified unless the existing condition exceeds the standard or unless otherwise provided in Subsection D of Section 20.6.2.3109 NMAC. Regardless of whether there is one contaminant or more than one contaminant present in ground water, when an existing pH or concentration of any water contaminant exceeds the standard specified in Subsection A, B, or C of this section, the existing pH or concentration shall be the allowable limit, provided that the discharge at such concentrations will not result in concentrations at any place of withdrawal for present or reasonably foreseeable future use in excess of the standards of this section. These standards shall apply to the dissolved portion of the contaminants specified with a definition of dissolved being that given in the publication "*methods for chemical analysis of water and waste of the U.S. environmental protection agency*," with the exception that standards for mercury, organic compounds and non-aqueous phase liquids shall apply to the total unfiltered concentrations of the contaminants.

A. **Human Health Standards**-Ground water shall meet the standards of Subsection A and B of this section unless otherwise provided. If more than one water contaminant affecting human health is present, the toxic pollutant criteria as set forth in the definition of toxic pollutant in Section 20.6.2.1101 NMAC for the combination of contaminants, or the Human Health Standard of Subsection A of Section 20.6.2.3103 NMAC for each contaminant shall apply, whichever is more stringent. Non-aqueous phase liquid shall not be present floating atop of or immersed within ground water, as can be reasonably measured.

(1) Arsenic (As)....................0.1 mg/l
(2) Barium (Ba)....................1.0 mg/l
(3) Cadmium (Cd)....................0.01 mg/l
(4) Chromium (Cr)....................0.05 mg/l
(5) Cyanide (CN)....................0.2 mg/l
(6) Fluoride (F)....................1.6 mg/l
(7) Lead (Pb)....................0.05 mg/l
(8) Total Mercury (Hg)....................0.002 mg/l
(9) Nitrate (NO_3 as N)....................10.0 mg/l
(10) Selenium (Se)....................0.05 mg/l
(11) Silver (Ag)....................0.05 mg/l
(12) Uranium (U)....................0.03 mg/l
(13) Radioactivity: Combined Radium-226 & Radium-228....................30 pCi/l
(14) Benzene....................0.01 mg/l
(15) Polychlorinated biphenyls (PCB's)....................0.001 mg/l
(16) Toluene....................0.75 mg/l
(17) Carbon Tetrachloride....................0.01 mg/l
(18) 1,2-dichloroethane (EDC)....................0.01 mg/l
(19) 1,1-dichloroethylene (1,1-DCE)....................0.005 mg/l
(20) 1,1,2,2-tetrachloroethylene (PCE)....................0.02 mg/l
(21) 1,1,2-trichloroethylene (TCE)....................0.1 mg/l
(22) ethylbenzene....................0.75 mg/l
(23) total xylenes....................0.62 mg/l
(24) methylene chloride....................0.1 mg/l
(25) chloroform....................0.1 mg/l
(26) 1,1-dichloroethane....................0.025 mg/l
(27) ethylene dibromide (EDB)....................0.0001 mg/l
(28) 1,1,1-trichloroethane....................0.06 mg/l
(29) 1,1,2-trichloroethane....................0.01 mg/l
(30) 1,1,2,2-tetrachloroethane....................0.01 mg/l
(31) vinyl chloride....................0.001 mg/l
(32) PAHs: total naphthalene plus monomethylnaphthalenes....................0.03 mg/l
(33) benzo-a-pyrene....................0.0007 mg/l

B. **Other Standards for Domestic Water Supply**

(1) Chloride (Cl)....................250.0 mg/l
(2) Copper (Cu)....................1.0 mg/l
(3) Iron (Fe)....................1.0 mg/l
(4) Manganese (Mn)....................0.2 mg/l
(6) Phenols....................0.005 mg/l
(7) Sulfate (SO_4)....................600.0 mg/l
(8) Total Dissolved Solids (TDS)....................1000.0 mg/l
(9) Zinc (Zn)....................10.0 mg/l
(10) pH....................between 6 and 9

C. **Standards for Irrigation Use - Ground water shall meet the standards of Subsection A, B, and C of this section unless otherwise provided.**

(1) Aluminum (Al)....................5.0 mg/l
(2) Boron (B)....................0.75 mg/l
(3) Cobalt (Co)....................0.05 mg/l

(4) Molybdenum (Mo) ....1.0 mg/l
(5) Nickel (Ni) ....0.2 mg/l

[2-18-77, 1-29-82, 11-17-83, 3-3-86, 12-1-95; 20.6.2.3103 NMAC - Rn, 20 NMAC 6.2.III.3103, 1-15-01; A, 9-26-04]
[Note: For purposes of application of the amended numeric uranium standard to past and current water discharges (as of 9-26-04), the new standard will not become effective until June 1, 2007. For any new water discharges, the uranium standard is effective 9-26-04.]

20.6.2.3104 DISCHARGE PERMIT REQUIRED: Unless otherwise provided by this Part, no person shall cause or allow effluent or leachate to discharge so that it may move directly of indirectly into ground water unless he is discharging pursuant to a discharge permit issued by the secretary. When a permit has been issued, discharges must be consistent with the terms and conditions of the permit. In the event of a transfer of the ownership, control, or possession of a facility for which a discharge permit is in effect, the transferee shall have authority to discharge under such permit, provided that the transferee has complied with Section 20.6.2.3111 NMAC, regarding transfers.
[2-18-77, 12-24-87, 12-1-95; Rn & A, 20.6.2.3104 NMAC - 20 NMAC 6.2.III.3104, 1-15-01; A, 12-1-01]

20.6.2.3105 EXEMPTIONS FROM DISCHARGE PERMIT REQUIREMENT: Sections 20.6.2.3104 and 20.6.2.3106 NMAC do not apply to the following:

A. Effluent or leachate which conforms to all the listed numerical standards of Section 20.6.2.3103 NMAC and has a total nitrogen concentration of 10 mg/l or less, and does not contain any toxic pollutant. To determine conformance, samples may be taken by the agency before the effluent or leachate is discharged so that it may move directly or indirectly into ground water; provided that if the discharge is by seepage through non-natural or altered natural materials, the agency may take samples of the solution before or after seepage. If for any reason the agency does not have access to obtain the appropriate samples, this exemption shall not apply;

B. Effluent which is discharged from a sewerage system used only for disposal of household and other domestic waste which is designed to receive and which receives 2,000 gallons or less of liquid waste per day;

C. Water used for irrigated agriculture, for watering of lawns, trees, gardens or shrubs, or for irrigation for a period not to exceed five years for the revegetation of any disturbed land area, unless that water is received directly from any sewerage system;

D. Discharges resulting from the transport or storage of water diverted, provided that the water diverted has not had added to it after the point of diversion any effluent received from a sewerage system, that the source of the water diverted was not mine workings, and that the secretary has not determined that a hazard to public health may result;

E. Effluent which is discharged to a watercourse which is naturally perennial; discharges to dry arroyos and ephemeral streams are not exempt from the discharge permit requirement, except as otherwise provided in this section;

F. Those constituents which are subject to effective and enforceable effluent limitations in a National Pollutant Discharge Elimination System (NPDES) permit, where discharge onto or below the surface of the ground so that water contaminants may move directly or indirectly into ground water occurs downstream from the outfall where NPDES effluent limitations are imposed, unless the secretary determines that a hazard to public health may result. For purposes of this subsection, monitoring requirements alone do not constitute effluent limitations;

G. Discharges resulting from flood control systems;

H. Leachate which results from the direct natural infiltration of precipitation through disturbed materials, unless the secretary determines that a hazard to public health may result;

I. Leachate which results entirely from the direct natural infiltration of precipitation through undisturbed materials;

J. Leachate from materials disposed of in accordance with the Solid Waste Management Regulations (20 NMAC 9.1) adopted by the New Mexico Environmental Improvement Board;

K. Natural ground water seeping or flowing into conventional mine workings which re-enters the ground by natural gravity flow prior to pumping or transporting out of the mine and without being used in any mining process; this exemption does not apply to solution mining;

L. Effluent or leachate discharges resulting from activities regulated by a mining plan approved and permit issued by the New Mexico Coal Surface Mining Commission, provided that this exemption shall not be construed as limiting the application of appropriate ground water protection requirements by the New Mexico Coal Surface Mining Commission;

M. Effluent or leachate discharges which are regulated by the Oil Conservation Commission and the regulation of which by the Water Quality Control Commission would interfere with the exclusive authority granted under Section 70-2-12 NMSA 1978, or under other laws, to the Oil Conservation Commission.
[2-18-77, 6-26-80, 7-2-81, 12-24-87, 12-1-95; 20.6.2.3105 NMAC - Rn, 20 NMAC 6.2.III.3105, 1-15-01; A, 12-1-01]

20.6.2.3106 APPLICATION FOR DISCHARGE PERMITS AND RENEWALS:

A. Any person who, before or on June 18, 1977, is discharging any of the water contaminants listed in Section 20.6.2.3103 NMAC or any toxic pollutant so that they may move directly or indirectly into ground water shall, within 120 days of receipt of written notice from the secretary that a discharge permit is required, or such longer time as the secretary shall for good cause allow, submit a discharge plan to the secretary for approval; such person may discharge without a discharge permit until 240 days after written notification by the secretary that a discharge permit is required or such longer time as the secretary shall for good cause allow.

B. Any person who intends to begin, after June 18, 1977, discharging any of the water contaminants listed in Section 20.6.2.3103 NMAC or any toxic pollutant so that they may move directly or indirectly into ground water shall notify the secretary giving the information enumerated in Subsection B of Section 20.6.2.1201NMAC; the secretary shall, within 60 days, notify such person if a discharge permit is required; upon submission, the secretary shall review the discharge plan pursuant to Sections 20.6.2.3108 and 20.6.2.3109 NMAC. For good cause shown the secretary may allow such person to discharge without a discharge permit for a period not to exceed 120 days.

C. A proposed discharge plan shall set forth in detail the methods or techniques the discharger proposes to use or processes expected to naturally occur which will ensure compliance with this Part. At least the following information shall be included in the plan:

(1) Quantity, quality and flow characteristics of the discharge;

(2) Location of the discharge and of any bodies of water, watercourses and ground water discharge sites within one mile of the outside perimeter of the discharge site, and existing or proposed wells to be used for monitoring;

(3) Depth to and TDS concentration of the ground water most likely to be affected by the discharge;

(4) Flooding potential of the site;

(5) Location and design of site(s) and method(s) to be available for sampling, and for measurement or calculation of flow;

(6) Depth to and lithological description of rock at base of alluvium below the discharge site if such information is available;

(7) Any additional information that may be necessary to demonstrate that the discharge permit will not result in concentrations in excess of the standards of Section 20.6.2.3103 NMAC or the presence of any toxic pollutant at any place of withdrawal of water for present or reasonably foreseeable future use. Detailed information on site geologic and hydrologic conditions may be required for a technical evaluation of the applicant's proposed discharge plan; and

(8) Additional detailed information required for a technical evaluation of underground injection control wells as provided in Sections 20.6.2.5000 through 20.6.2. 5299 NMAC,

D. An applicant for a discharge permit shall pay fees as specified in Section 20.6.2.3114 NMAC.

E. An applicant for a permit to dispose of or use septage or sludge, or within a source category designated by the commission, may be required by the secretary to file a disclosure statement as specified in 74-6-5.1 of the Water Quality Act.

F. If the holder of a discharge permit submits an application for discharge permit renewal at least 120 days before the discharge permit expires, and the discharger is not in violation of the discharge permit on the date of its expiration, then the existing discharge permit for the same activity shall not expire until the application for renewal has been approved or disapproved. A discharge permit continued under this provision remains fully effective and enforceable. An application for discharge permit renewal must include and adequately address all of the information necessary for evaluation of a new discharge permit. Previously submitted materials may be included by reference provided they are current, readily available to the secretary and sufficiently identified to be retrieved.

[2-18-77, 6-26-80, 7-2-81, 9-20-82, 8-17-91, 12-1-95; 20.6.2.3106 NMAC - Rn, 20 NMAC 6.2.III.3106, 1-15-01; A, 12-1-01; A, 9-15-02]

20.6.2.3107 MONITORING, REPORTING, AND OTHER REQUIREMENTS:

A. Each discharge plan shall provide for the following as the secretary may require:

(1) The installation, use, and maintenance of effluent monitoring devices;

(2) The installation, use, and maintenance of monitoring devices for the ground water most likely to be affected by the discharge;

(3) Monitoring in the vadose zone;

(4) Continuation of monitoring after cessation of operations;

(5) Periodic submission to the secretary of results obtained pursuant to any monitoring requirements in the discharge permit and the methods used to obtain these results;

(6) Periodic reporting to the secretary of any other information that may be required as set forth in the discharge permit;

(7) The discharger to retain for a period of at least five years any monitoring data required in the discharge permit;

(8) A system of monitoring and reporting to verify that the permit is achieving the expected results;

(9) Procedures for detecting failure of the discharge system;

(10) Contingency plans to cope with failure of the discharge permit or system;

(11) A closure plan to prevent the exceedance of standards of Section 20.6.2.3103 NMAC or the presence of a toxic pollutant in ground water after the cessation of operation which includes: a description of closure measures, maintenance and monitoring plans, post-closure maintenance and monitoring plans, financial assurance, and other measures necessary to prevent and/or abate such contamination. The obligation to implement the closure plan as well as the requirements of the closure plan, if any is required, survives the termination or expiration of the permit. A closure plan for any underground injection control well must also incorporate the applicable requirements of Sections 20.6.2.5005 and 20.6.2.5209 NMAC.

B. Sampling and analytical techniques shall conform with the following references unless otherwise specified by the secretary:

(1) Standard Methods for the Examination of Water and Wastewater, latest edition, American Public Health Association; or

(2) Methods for Chemical Analysis of Water and Waste, and other publications of the Analytical Quality Laboratory, EPA; or

(3) Techniques of Water Resource Investigations of the U.S. Geological Survey; or

(4) Annual Book of ASTM Standards. Part 31. Water, latest edition, American Society For Testing and Materials; or

(5) Federal Register, latest methods published for monitoring pursuant to Resource Conservation and Recovery Act regulations; or

(6) National Handbook of Recommended Methods for Water-Data Acquisition, latest edition, prepared cooperatively by agencies of the United States Government under the sponsorship of the U.S. Geological Survey.

C. The discharger shall notify the secretary of any facility expansion, production increase or process modification that would result in any significant modification in the discharge of water contaminants.

D. Any discharger of effluent or leachate shall allow any authorized representative of the secretary to:

(1) inspect and copy records required by a discharge permit;

(2) inspect any treatment works, monitoring and analytical equipment;

(3) sample any effluent before or after discharge;

(4) use monitoring systems and wells installed pursuant to a discharge permit requirement in order to collect samples from ground water or the vadose zone.

E. Each discharge permit for an underground injection control well shall incorporate the applicable requirements of Sections

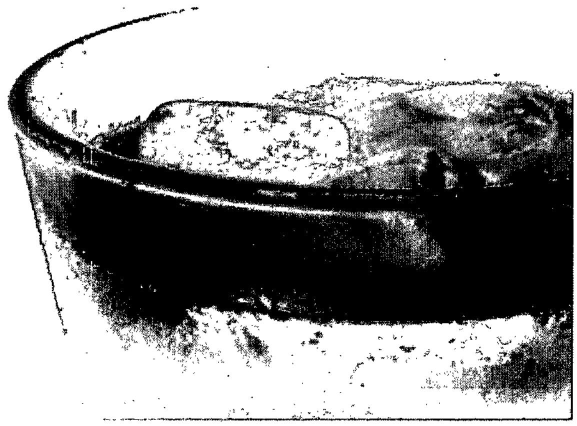
REFERENCES

30-31

http://www.epa.gov/safewater/contaminants/index.html
Last updated on Thursday, June 5th, 2008.

Drinking Water Contaminants

On this page



National Primary Drinking Water Regulations

National Primary Drinking Water Regulations (NPDWRs or primary standards) are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water. Visit the list of regulated contaminants with links for more details.

- List of Contaminants & their Maximum Contaminant Level (MCLs)
- Setting Standards for Safe Drinking Water to learn about EPA's standard-setting process
- EPA's Regulated Contaminant Timeline (PDF) (1 pp, 86 K) (About PDF)
- National Primary Drinking Water Regulations- The complete regulations regarding these contaminants availible from the Code of Federal Regulations Website

List of Contaminants & their MCLs

- Microorganisms
- Disinfectants
- Disinfection Byproducts
- Inorganic Chemicals
- Organic Chemicals
- Radionuclides

Information on this section

- Alphabetical List (PDF) (6 pp, 396 K) (About PDF) EPA 816-F-03-016, June 2003
- The links provided below are to either Consumer Fact Sheet, Rule Implementation web sites, or PDF files. (About PDF)

Microorganisms

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Cryptosporidium df file)	zero	TT [3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste
Giardia lamblia	zero	TT[3]		

			Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste
Heterotrophic plate count	n/a	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment
Legionella	zero	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and *E. Coli*)	zero	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.
Turbidity	n/a	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff
Viruses (enteric)	zero	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste

Disinfection Byproducts

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Bromate	zero	0.010	Increased risk of cancer	Byproduct of drinking water disinfection

Chlorite	0.8	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection
Haloacetic acids (HAA5)	n/a[6]	0.060[7]	Increased risk of cancer	Byproduct of drinking water disinfection
Total Trihalomethanes (TTHMs)	n/a[6]	0.080[7]	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection

Disinfectants

Contaminant	MRDLG[1] (mg/L)[2]	MRDL[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Chloramines (as Cl_2)	MRDLG=4[1]	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes
Chlorine (as Cl_2)	MRDLG=4[1]	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes
Chlorine dioxide (as ClO_2)	MRDLG=0.8[1]	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes

Inorganic Chemicals

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0[7]	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronicsproduction wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal

				refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	TT[8]; Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	TT[8]; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high	Corrosion of household plumbing systems; erosion of natural deposits

Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2		

			Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

Radionuclides

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Alpha particles	none[7] ---------- zero	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation
Beta particles and photon emitters	none[7] ---------- zero	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation
Radium 226 and Radium 228 (combined)	none[7] ---------- zero	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
Uranium	zero		Increased risk of cancer, kidney toxicity	Erosion of natural deposits

p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1,1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1,2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories
1,2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl) adipate	0.4	0.4	Weight loss, liver problems, or possible reproductive difficulties.	Discharge from chemical factories
Di(2-ethylhexyl) phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02		

			Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Liver problems	Residue of banned insecticide
Epichlorohydrin	zero	TT[9]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals
Ethylbenzene	0.7	0.7	Liver or kidneys problems	Discharge from petroleum refineries
Ethylene dibromide	zero	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens

			blood pressure	
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (measured as Nitrogen)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories

Organic Chemicals

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Acrylamide	zero	TT[9]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops

Atrazine	0.003	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene (PAHs)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories

30 ug/L
as of
12/08/03

Notes

[1] Definitions:
Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
Maximum Residual Disinfectant Level (MRDL) - The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
Maximum Residual Disinfectant Level Goal (MRDLG) - The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
Treatment Technique - A required process intended to reduce the level of a contaminant in drinking water.

[2] Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- Cryptosporidium: (as of1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- Giardia lamblia: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- Legionella: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter.
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, Cryptosporidium removal requirements, updated watershed control requirements for unfiltered systems).
- Long Term 2 Enhanced Surface Water Treatment Rule (Effective Date: January 4, 2006) - Surface water systems or GWUDI systems must comply with the additional treatment for Cryptosporidium specified in this rule based on their Cryptosporidium bin classification calculated after the completion of source water monitoring.
- Filter Backwash Recycling; The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

[4] more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample

that has total coliform must be analyzed for either fecal coliforms or E. coli if two consecutive TC-positive samples, and one is also positive for E.coli fecal coliforms, system has an acute MCL violation.

[5] Fecal coliform and E. coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

[6] Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L): chloroform (0.07mg/L).
- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.02 mg/L); monochloroacetic acid (0.07 mg/L). Bromoacetic acid and dibromoacetic acid are regulated with this group but have no MCLGs.

[7] The MCL values are the same in the Stage 2 DBPR as they were in the Stage 1 DBPR, but compliance with the MCL is based on different calculations. Under Stage 1, compliance is based on a running annual average (RAA). Under Stage 2, compliance is based on a locational running annual average (LRAA), where the annual average at each sampling location in the distribution system is used to determine compliance with the MCLs. The LRAA requirement will become effective April 1, 2012 for systems on schedule 1, October 1, 2012 for systems on schedule 2, and October 1, 2013 for all remaining systems.

[8] Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

[9] Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
- Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

- National Secondary Drinking Water Regulations - The complete regulations regarding these contaminants available from the Code of Federal Regulations Web Site.
- For more information, read Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals.

List of National Secondary Drinking Water Regulations

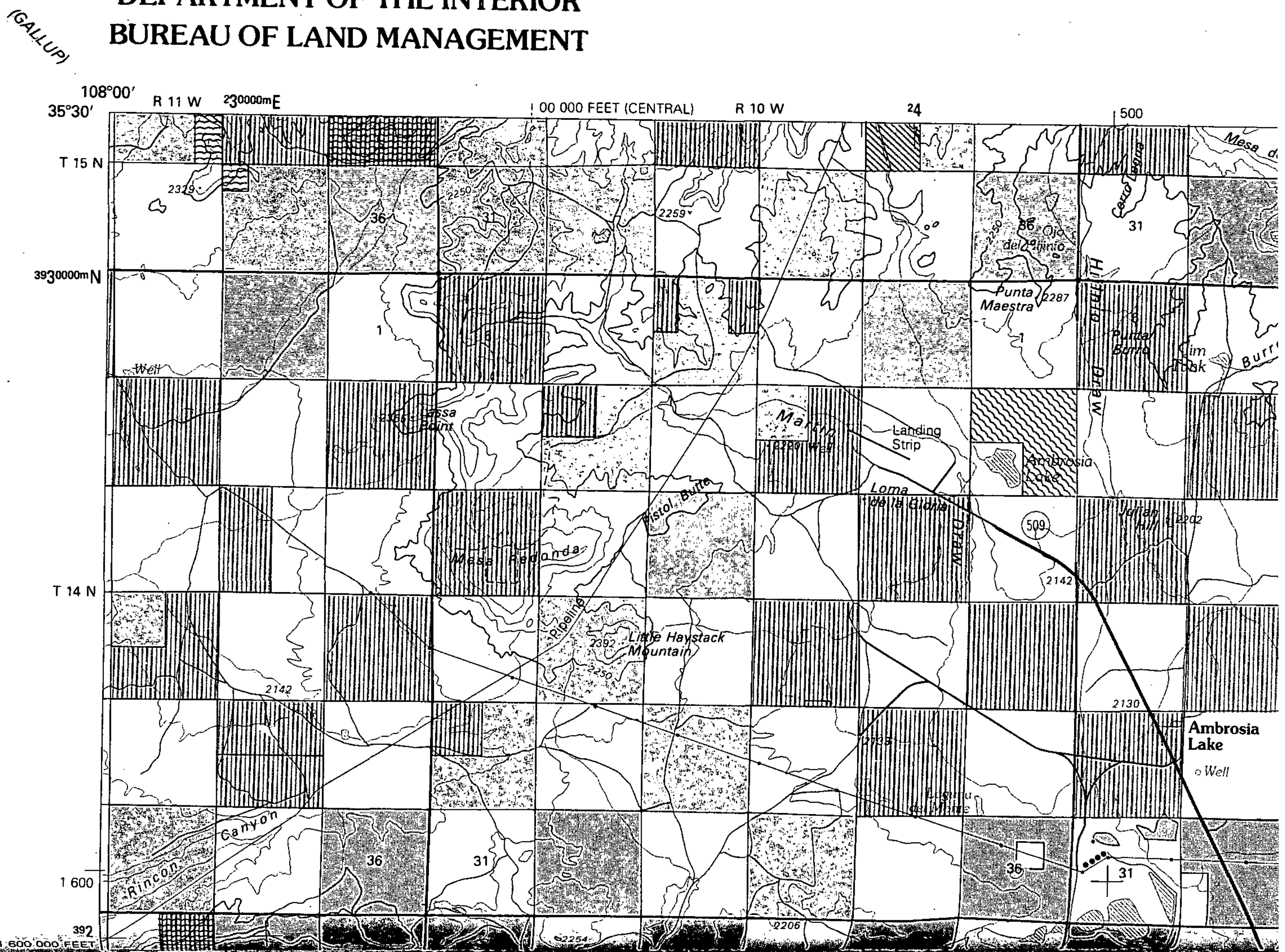
Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

Unregulated Contaminants

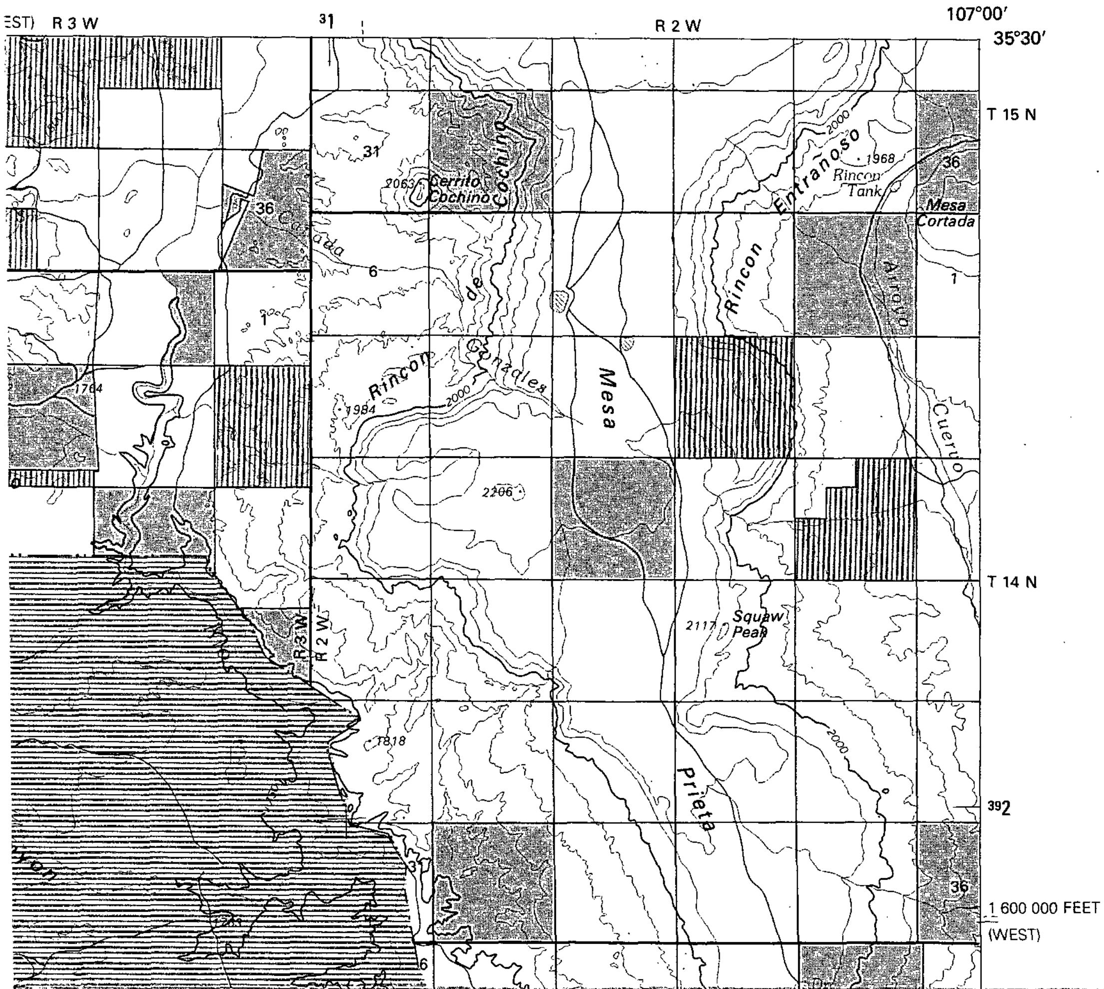
This list of contaminants which, at the time of publication, are not subject to any proposed or promulgated national primary drinking water regulation (NPDWR), are known or anticipated to occur in public water systems, and may require regulations under SDWA. For more information check out the list, or vist the Drinking Water Contaminant Candidate List (CCL) web site.

- Drinking Water Contaminant Candidate List 2
- Drinking Water Contaminant Candidate List (CCL) Web Site
- Unregulated Contaminant Monitoring Program (UCM)
- **Information on specific unregulated contaminants**
    - MTBE (methyl-t-butyl ether) in drinking water

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT



GRANTS QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES (TOPOGRAPHIC)



BUREAU OF LAND MANAGEMENT

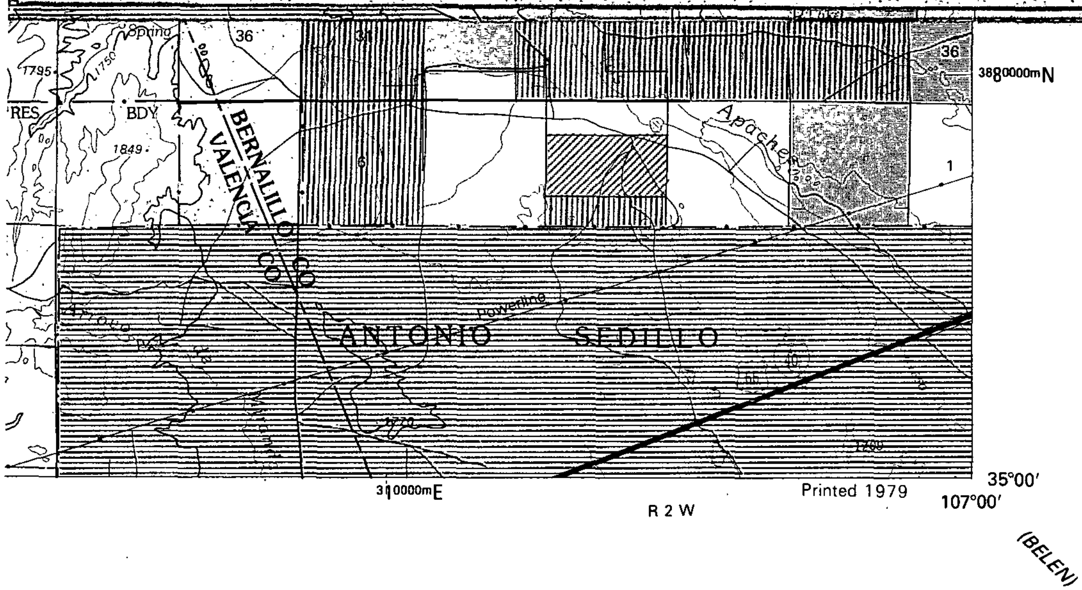
LAND STATUS LEGEND

Public Lands (Administered By Bureau of Land Management) . . . . .

Oregon & California Lands (O&C Lands) Coos Bay Wagon Road (CBWR) . . . . NONE

National Forest . . . .

National Grasslands . . . . NONE



and mineral rights, may have been shown as patented lands due to the lack of information available to BLM with respect to the nature of acquisition. Tracts less than 40 acres are usually omitted because of the map scale. Access through private lands may be restricted. The official land records in the respective offices of the Bureau of Land Management or other responsible Federal agencies should be checked for up-to-date status on any specific tract of land. Inadequacies in the BLM maps should be reported to the respective Bureau of Land Management offices from which the maps were obtained.

ROAD CLASSIFICATION

Primary highway, hard surface . . . .

Secondary highway, hard surface. . . . .

Light-duty road, hard or improved surface . . . . .

Street or other road . . . .

Trail . . . .

Interstate route   U.S. route   State route

GRANTS, NEW MEXICO

SW/4 ALBUQUERQUE (NI 13-1) 1:250 000-SCALE MAP

N3500–W10700/30x60

1978

SURFACE-MINERALS MANAGEMENT STATUS

RIOR
MENT

GRANTS
NE
1:100 000-SCALE